EXHIBIT G

Exponent Engineering, PC.

Exponent®

Gerard v. Omega Flex

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March 20, 2016

QAID: 1306636.EX0 - 9685

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Executive Summary

Exponent Engineering, PC. (Exponent) was retained by Omega Flex, Inc. to investigate a fire that occurred at the Gerard residence, located at 2511 Amelith Road, Bay City, Michigan in the early morning of May 29, 2013. The residence was supplied with natural gas, which was distributed within the structure using a combination of black iron pipe and TracPipe brand corrugated stainless steel tubing (CSST). Lightning strike verification data indicated numerous lightning strikes in the vicinity of the Gerard home on the morning of the fire and the night before.

Materials reviewed

Exponent reviewed the photographs taken by Smith & Associates of the Gerard home on August 27, 2013. Exponent also reviewed lightning data from the National Lightning Detection Network for the day of the fire. Exponent also reviewed materials produced by the parties in this matter, including reports by Mr. Jack Hooker, and Mr. Michael Williams.

A full list of the material reviewed in this matter is provided in Appendix A.

Inspections

Exponent and other parties also performed laboratory examinations of the evidence retained from the Gerard residence at the Williams & Beck Inc. Laboratory on December 5, 2013. Microscopic examination of the TracPipe CSST was performed using a stereomicroscope.

Testing

Exponent performed testing involving exemplar TracPipe. A detailed description of these tests and the test results are presented in Appendices C and D. The tests include:

1. TRACPIPE AND BRANCH CIRCUIT WIRING IN A FIRE ENVIRONMENT: Exponent performed testing in which TracPipe was placed in close proximity to energized branch circuit wiring (with several different configurations) and then subjected to a fire environment. A detailed description of this testing can be found in Appendix C.

2. GAS JET IGNITION TESTS: In these tests, the jacket of TracPipe was removed and holes of various sizes were drilled into the tubing wall. The TracPipe was supplied with fuel gas at household line pressures and Exponent attempted to ignite the escaping gas to identify the conditions under which the gas jet would and would not ignite. Tests were performed without the presence of any obstruction in the vicinity of the gas jet and with an obstruction placed at various distances from the hole in the TracPipe. A detailed description of this testing can be found in Appendix D.

3. ARC IGNITION TESTING: Testing was also performed in which an arc was generated between a copper electrode and a section of TracPipe pressurized with fuel gas, with its yellow jacket present. This testing was performed to determine under what conditions a

hole in the tubing wall could be formed, and if a hole formed, whether or not the escaping gas was ignited. A detailed description of this testing can be found in Appendix D.

Findings and opinions

Based on my education, background, training, experience, testing, analysis, and my review of the relevant materials, I offer the following opinions to a reasonable degree of engineering and scientific certainty. My curriculum vitae, including a list of publications, are provided in Appendix E. If additional information becomes available, I reserve the right to modify or amend these findings:

1. TracPipe is a safe and effective product for distributing fuel gas throughout a residence when it is installed and maintained in accordance with the Omega Flex TracPipe Flexible Gas Piping Design Guide and Installation Instructions (D&I Guide).

    a. A TracPipe gas distribution system in a home is less prone to leaks than black iron pipe gas distribution systems. This is because black iron pipe typically requires more fittings and joints than TracPipe.

    b. TracPipe is more flexible than black iron pipe and therefore is less susceptible to damage than black iron pipe during acts of nature such as earthquakes, ground swell, sink holes, tornados, landslides, floods, and hurricanes that may cause structural damage to a residence. The flexibility of TracPipe also allows for movement of the piping without damaging the joints during thermal expansion and contraction.

    c. Bare copper tubing and black iron pipe do not have an electrically insulating jacket. For this reason, they are more likely to be involved in arcing during lightning events than TracPipe for a given separation distance and piping geometry. Thus, copper tubing and black iron pipe are more likely to contribute to ignition of a fire during a lightning event than TracPipe.

2. Lightning energy can enter a home directly or indirectly, often through metallic roof penetrations, metal roofs, the household electrical system, or other utilities. The energy from lightning may cause multiple independent fires throughout a home due to electrical arcing.

3. Electrical arcs are high-temperature luminous electric discharges, which are capable of igniting combustible materials such as wood, paper, dust or other lightweight combustible materials. Electrical arcs of sufficient magnitude and duration can also cause a hole to form in TracPipe by localized melting of the stainless steel.

4. Fuel gas leaking from a hole in a TracPipe line at household line pressures cannot be ignited by an ignition source located at the hole because the gas velocity is too high and the gas concentration is too high at this location.

5. The fire in the Gerard home originated in the bottom compartment of the fireplace in the living room. The fire was witnessed by Mr. Gerard. There may have been additional independent areas of fire origin within the basement of the home.

6. Two holes caused by electrical activity were found in the flexible gas connector located in the compartment underneath the living room fireplace. The source of energy for the electrical activity was the direct lightning strike to the chimney cap for the fireplace flue pipe.

7. Two holes caused by electrical activity were found in the TracPipe CSST that ran to the fireplace. The source of energy for the larger of the two holes was the household electrical system. The source of energy for the smaller of the two holes was either the household electrical system or the direct lightning strike to the chimney cap for the fireplace flue pipe.

8. The cause of the fire in the Gerard home was a lightning strike. Lightning directly struck the chimney cap for the living room fireplace flue and was conductucted down the flue pipe, resulting in electrical arcing within the area or areas of origin.

    a. Potential first fuels that could have been ignited by lightning-related arcing include lightweight combustible materials such as fibers, dust, or other combustible debris.
    b. The burning lightweight combustibles quickly lead to ignition of natural gas leaking from the holes in the flexible gas connector in the bottom compartment of the fireplace, as observed by Mr. Gerard.

9. The fire in the Gerard home would have occurred regardless of the presence of TracPipe CSST.

10. The Gerard residence was not outfitted with an NFPA 780 compliant Lightning Protection System (LPS).

    a. Installing an NFPA 780 compliant LPS is the recognized industry standard method to protect a structure or its components from damage, including fire, in the event of lightning.

    b. Had the Gerard home utilized an NFPA 780 compliant LPS, this fire would likely not have occurred.

Note that this Executive Summary does not contain all of Exponent's technical evaluations, analyses, and conclusions that are found in the main body of this report and the appendices. Exponent reserves the right to modify these opinions in the event new information is discovered.

Incident Background

In the early morning of May 29, 2013, Mr. Richard Gerard reported being "half-asleep" on his couch, facing the living room fireplace. At around 1:30 AM, he saw a flash of lightning and heard a "very loud" crack of thunder. Mr. Gerard sat up and saw flames coming from the front of the fireplace, near the bottom.[1]

Mr. Gerard then checked the bedrooms and the bathroom for fire, but did not see any other fire. At this point, the smoke alarms in the home went off. Mr. Gerard then called 911. The operator asked if he could turn off the gas supply. Mr. Gerard then went outside and closed the supply valve for the gas.[2] From the front door, Mr. Gerard was able to see that there were no longer flames in front of the fireplace, however he saw a glow in the basement from a basement window, which prompted him to call 911 again.[3] The only flames Mr. Gerard saw were coming from the front of the fireplace directed toward the couch. Mr. Gerard did not see fire burning through the floor or through the wall in the vicinity of the fireplace.[4]

The Fire Department was notified of the fire at 1:47 AM and arrived at 2:00 AM. Upon arrival they observed smoke from the front door and heavy smoke inside the basement. Thermal imaging showed heat at the ceiling of the basement.[5]

Home construction and utilities

The Gerard home was built in 2006. Mr. Gerard was the original owner. An aerial photograph of the residence is shown in Figure 1 and a photograph of the front of the residence taken after the fire is shown in Figure 2.

[1] Deposition of Mr. Gerard. December 29, 2016. Pages 10-12.

[2] Deposition of Mr. Gerard. December 29, 2016. Pages 13-15.

[3] Deposition of Mr. Gerard. December 29, 2016. Pages 18-19.

[4] Deposition of Mr. Gerard. December 29, 2016. Pages 47-49.

[5] Frakenlust Twp Fire Department Incident Report. 2013-0000123-000

Figure 1. Aerial photograph of the Gerard home.[6] The front of the house faces south.

Figure 2. Photograph of the front of the Gerard residence after the fire.

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[6] From Google Maps.

A layout of the first floor living room with the fireplace and a schematic diagram of the utilities is shown in Figure 3. The home was supplied with natural gas at the northeast corner. Black iron pipe was used to connect the natural gas supply to a water heater and a furnace in the basement. A section of ½" nominal TracPipe CSST connected to a tee in the black iron pipe supply piping and ran along the basement ceiling to the bottom of the fireplace in the first floor living room. The TracPipe CSST connected to a flexible gas connector, which was connected to the gas valve in a compartment underneath the fireplace, as shown in Figure 4.

There were four holes found in the gas sytem after the fire. Two holes were on adjacent corrugations of the flexible gas connector in the bottom compartment of the fireplace. There were also two holes on the section of TracPipe CSST. These holes are described in more detail in the "Evidence Examination" section below. A more detailed description of TracPipe CSST is provided in Appendix B.

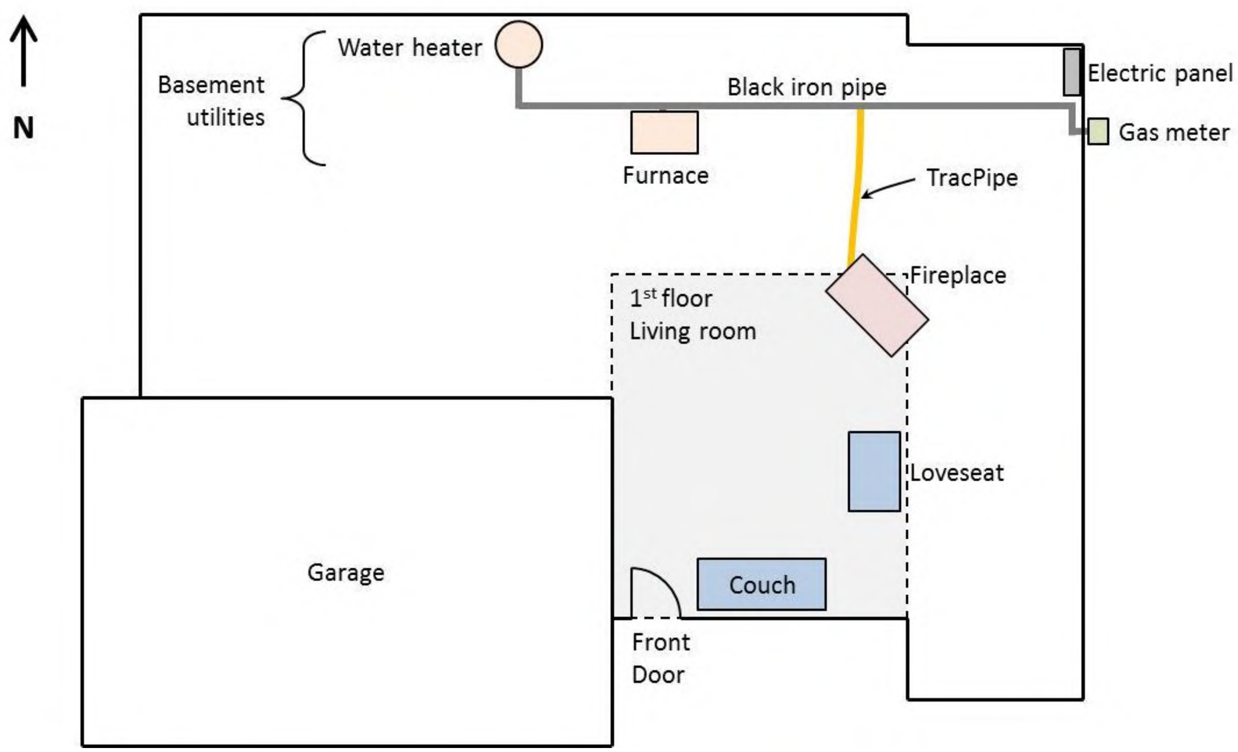

Figure 3. Schematic diagram of the Gerard residence showing utlity locations in the basement and the configuration of the living room. Not to scale.

Figure 4. Photograph of the fireplace from the living room of the Gerard home.

Lightning data

Exponent reviewed the CoreLogic lightning strike verification report (STRIKEnet Report) which records data collected by the National Lightning Detection Network (NLDN) for all lightning return strokes within 5.0 miles of the home between 3:00 AM on May 28, 2013 and 3:00 AM on May 29, 2013. [7] Detailed data including the millisecond time stamps associated with each of the return strokes was also obtained from Vaisala.

Analysis of the data and the timeline of events were used to identify the strokes that were most likely to have affected the Gerard home (see Table 1). The locations of these five strokes are shown in Figure 5. The five strokes were part of a single lightning flash at 1:44 AM.

[7] STRIKEnet Report # 3095280.

Table 1. Lightning return strokes with highest probability to have affected the Gerard home on May 29, 2013.

Date & Time	Peak Amplitude (kA)
5/29/13 1:43:59.015	-64.7
5/29/13 1:43:59.116	-40.2
5/29/13 1:43:59.157	-27.5
5/29/13 1:43:59.224	-36.3
5/29/13 1:43:59.291	-32.4

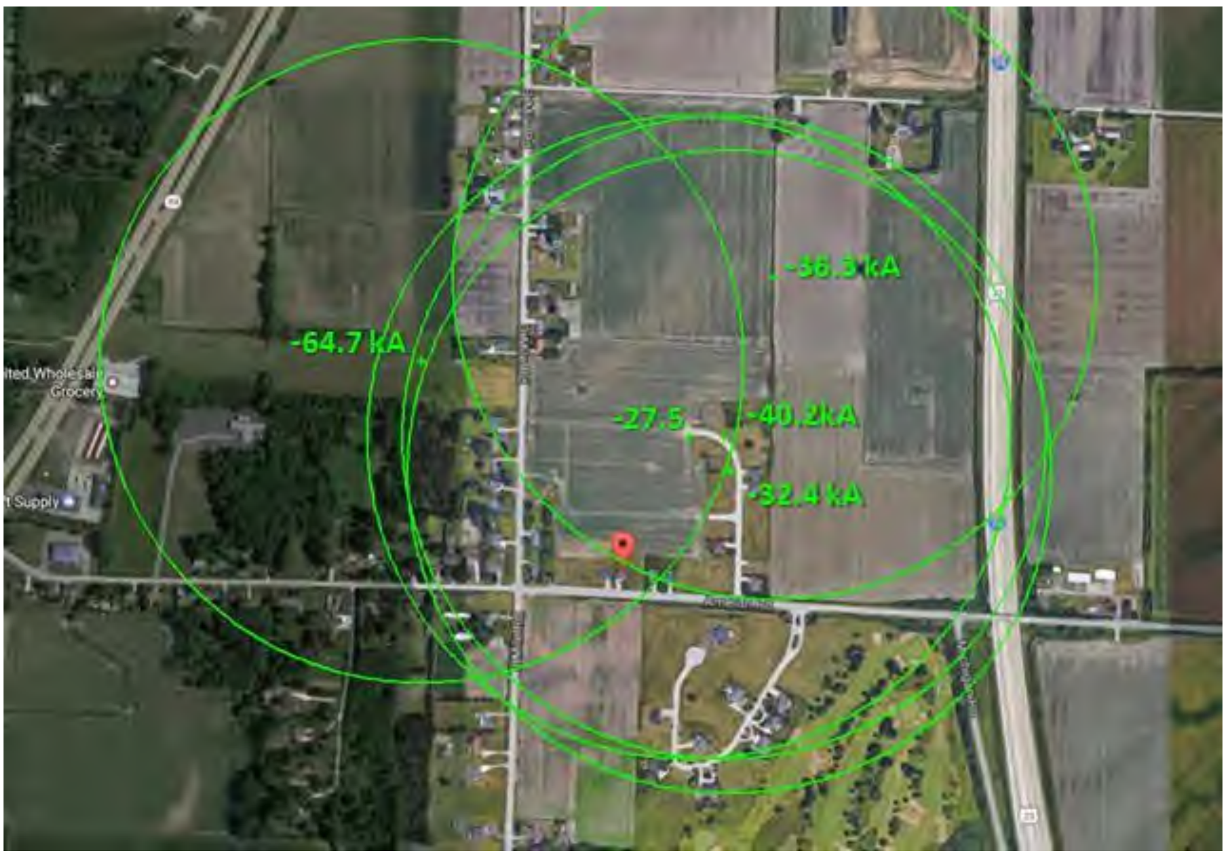

Figure 5. Map showing the location of the five lightning strokes in Table 1 and their confidence ellipses. The Gerard residence is indicated by the red balloon.[8]

[8] Underlying map obtained from Google Maps (accessed on March 26, 2017).

Origin of the fire

Mr. Gerard observed flames coming from the front of the base of the fireplace just after he heard the lightning strike. There was fire damage to the floor in the vicinity of the fireplace (see Figure 6 and Figure 7) and smoke damage throughout the first floor.

There was also fire damage in the basement, at the level of the basement ceiling, as shown in Figure 8 through Figure 10. The damage was most severe in the vicinity of the bottom of the fireplace, where floor joists had been completely consumed.

Based on the statements by Mr. Gerard, the locations of fire damage, and the locations of the holes in the flexible gas connectors, the fire originated in the bottom compartment of the living room fireplace. The fire damage to the basement ceiling is consistent with fire spreading from the base of the fireplace. However, there may also have been additional areas of fire origin in the basement at ceiling level.

Figure 6. Photograph of the living room fireplace. There was fire damage to the floor in front of the fireplace, covered by oriented strand boards in the photograph.

Figure 7. Photograph of the base of the living room fireplace. Fire had burned through the floor in this location. The TracPipe CSST line to the fireplace is also visible.

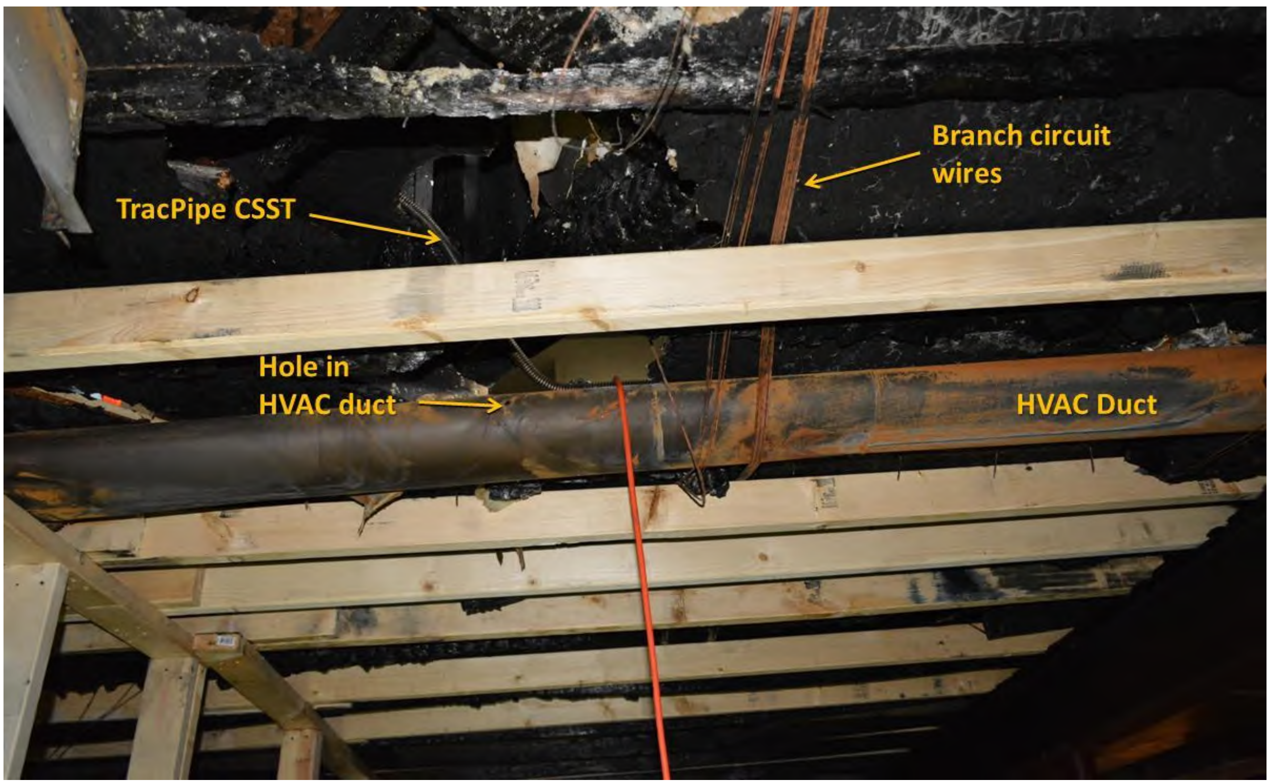

Figure 8. Photograph of the basement ceiling directly below the fireplace. The photographer is looking west. The unburned wooden members were installed for structural shoring after the fire.

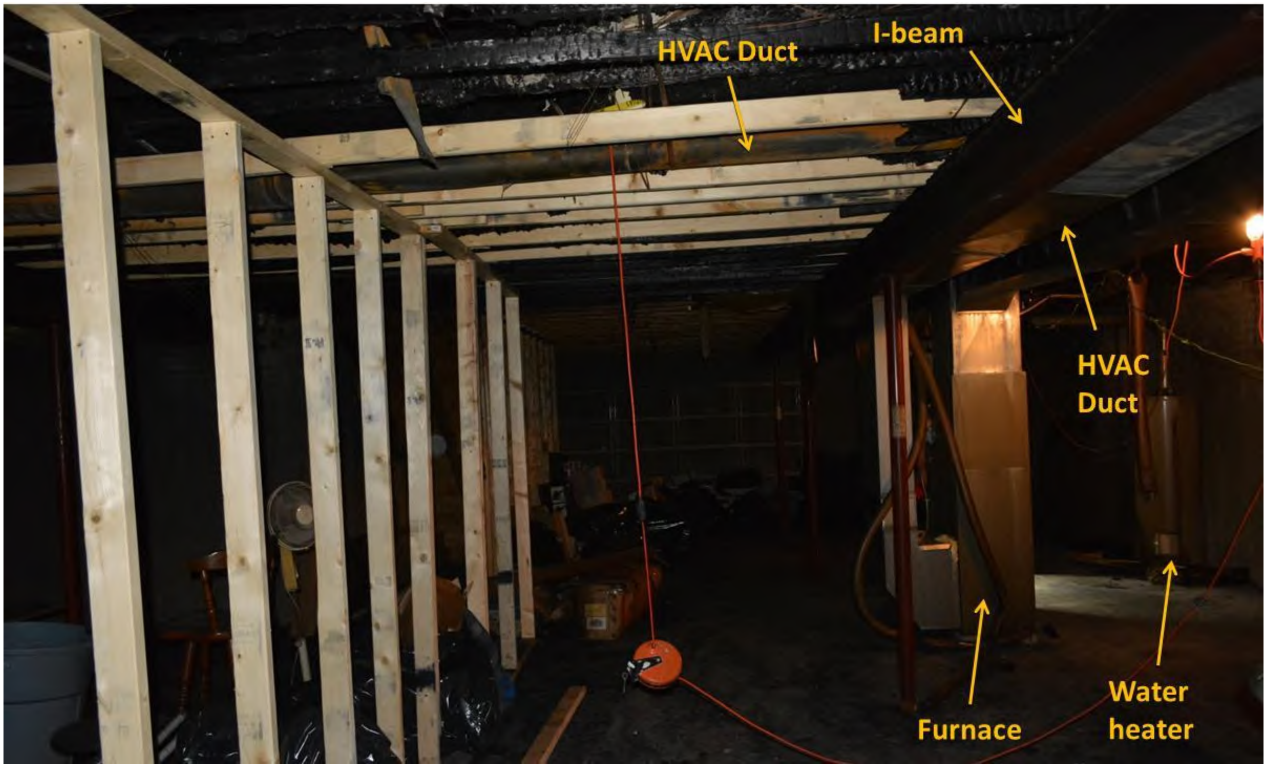

Figure 9. Photograph of the basement, looking west.

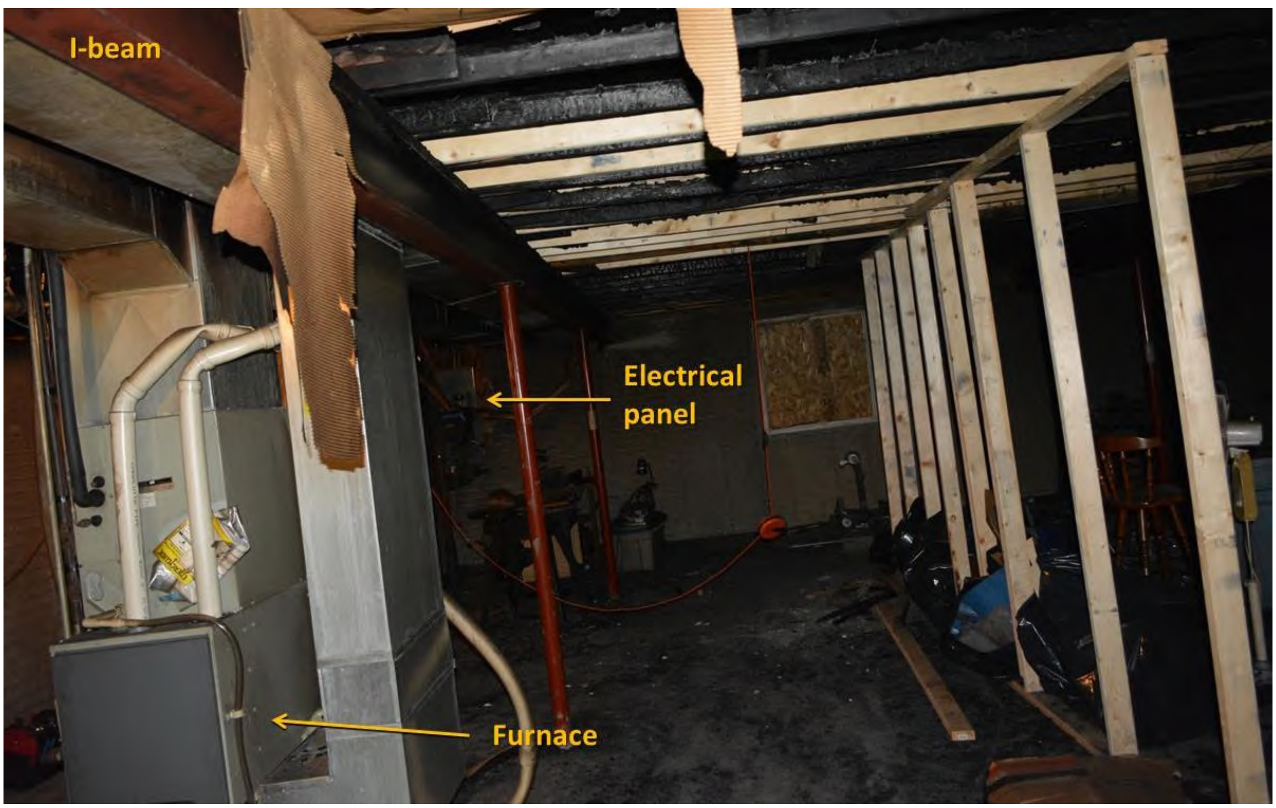

Figure 10. Photograph of the basement, looking east.

Evidence Examination

On December 5, 2013, Exponent participated in an examination of items removed from the Gerard home, performed at Williams & Beck Inc. in Cedar Springs, MI. The following five items were examined:

1. HVAC Duct
2. TracPipe CSST and fitting
3. Fireplace
4. CSST fitting
5. Fireplace flue pipe with chimney cap

HVAC Duct

The HVAC duct that was retained ran along the basement ceiling in the Gerard home from the north side (near the furnace) toward the south side, approximately parallel to the TracPipe CSST line to the fireplace. The duct comprised two sections, shown in Figure 11 and Figure 12.

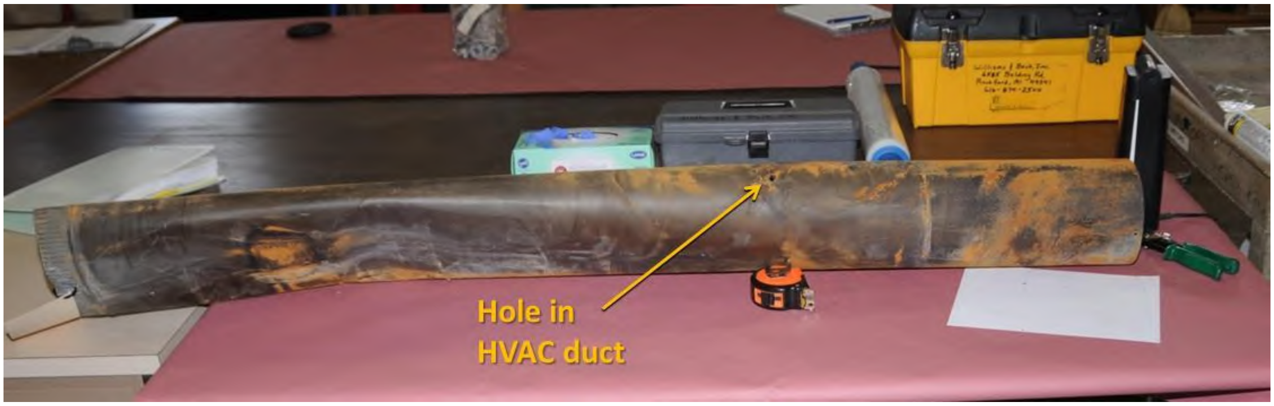

Figure 11. Photograph of the south section of the HVAC duct.

Figure 12. Photograph of the north section of the HVAC duct.

A hole was found in the south section of the HVAC duct. The location of the hole is shown above in Figure 8 and Figure 11. The hole had molten and resolidified metal around the edge (see Figure 13), indicating that it was caused by electrical arcing.

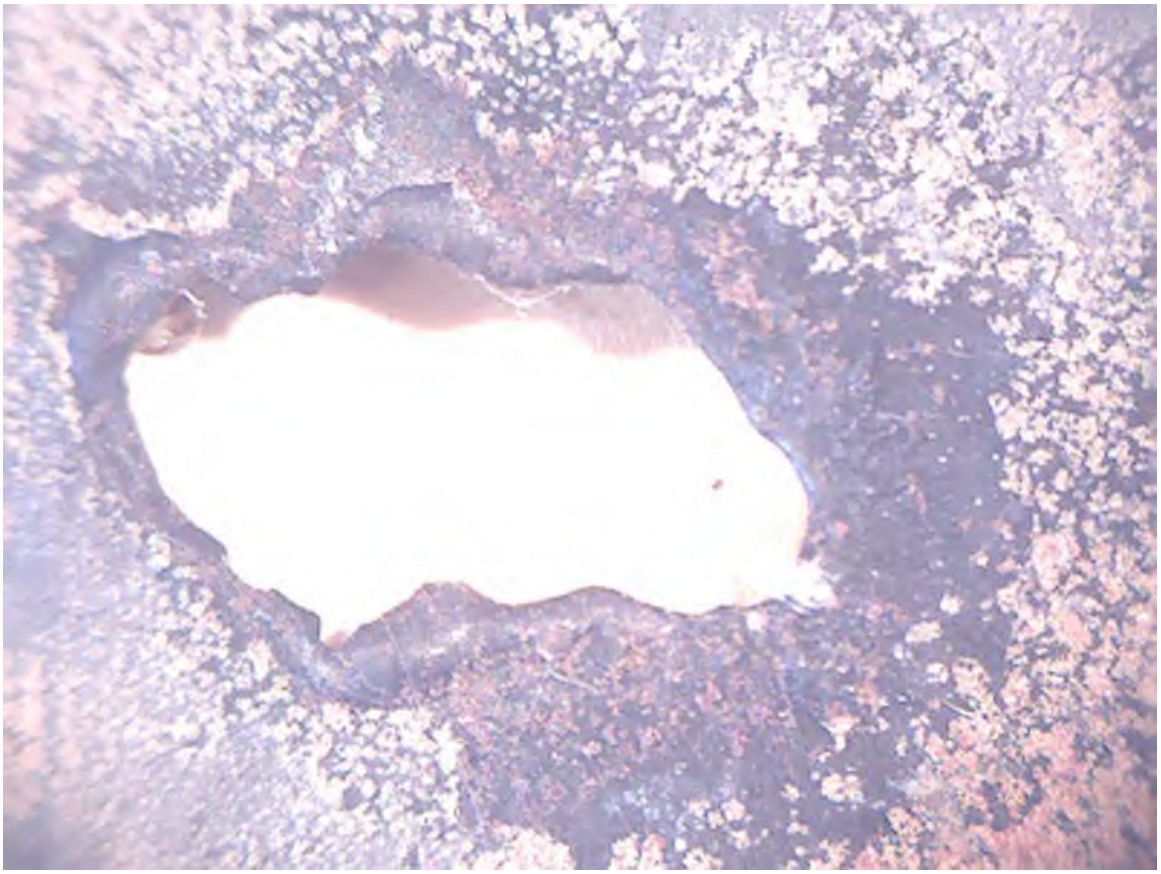

Figure 13. Optical microscope image of the hole in the HVAC duct.

Flue pipe and chimney cap

The flue pipe for the fireplace comprised multiple sections of double-walled vent piping (see Figure 14). It terminated at the top with a chimney cap (see Figure 15). There were multiple locations on the chimney cap where the metal had melted and resolidifed (see Figure 16 and Figure 17). This damage indicates that lightning direct struck the flue pipe chimney cap.

In addition to the electrical damage to the chimney cap, there was also electrical damage at the junction between adjacent sections of the flue piping, as shown in Figure 18 and Figure 19. This electrical damage is an additional indication that the flue piping was directly struck by lightning.

Figure 14. Photograph of the double-walled fireplace flue piping.

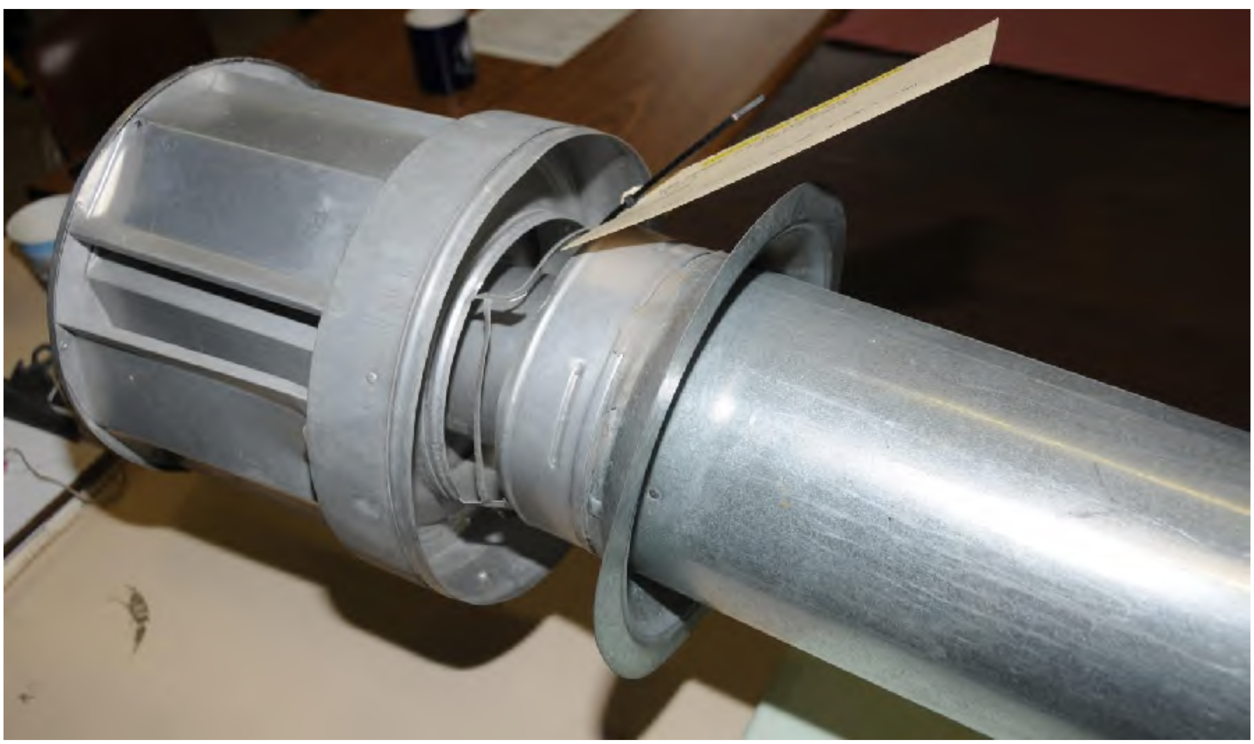

Figure 15. Photograph of the chimney cap at the top of the fireplace flue piping.

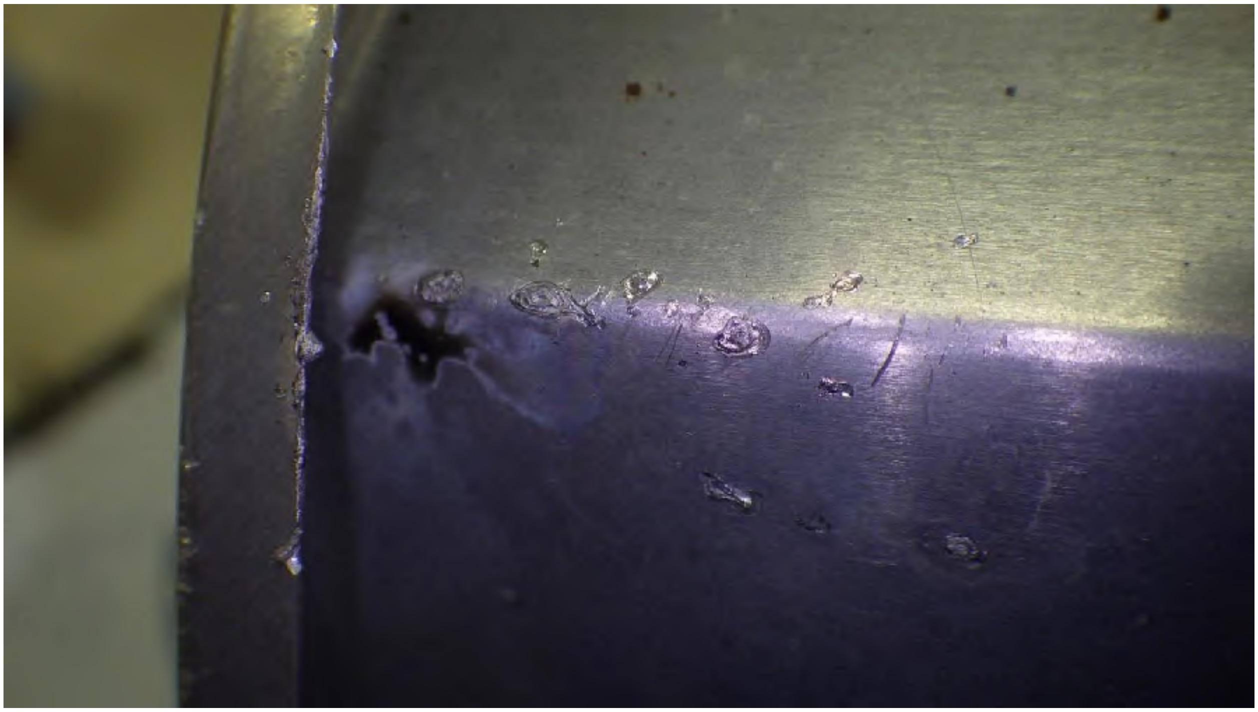

Figure 16. Example photograph of the electrical damage to the chimney cap.

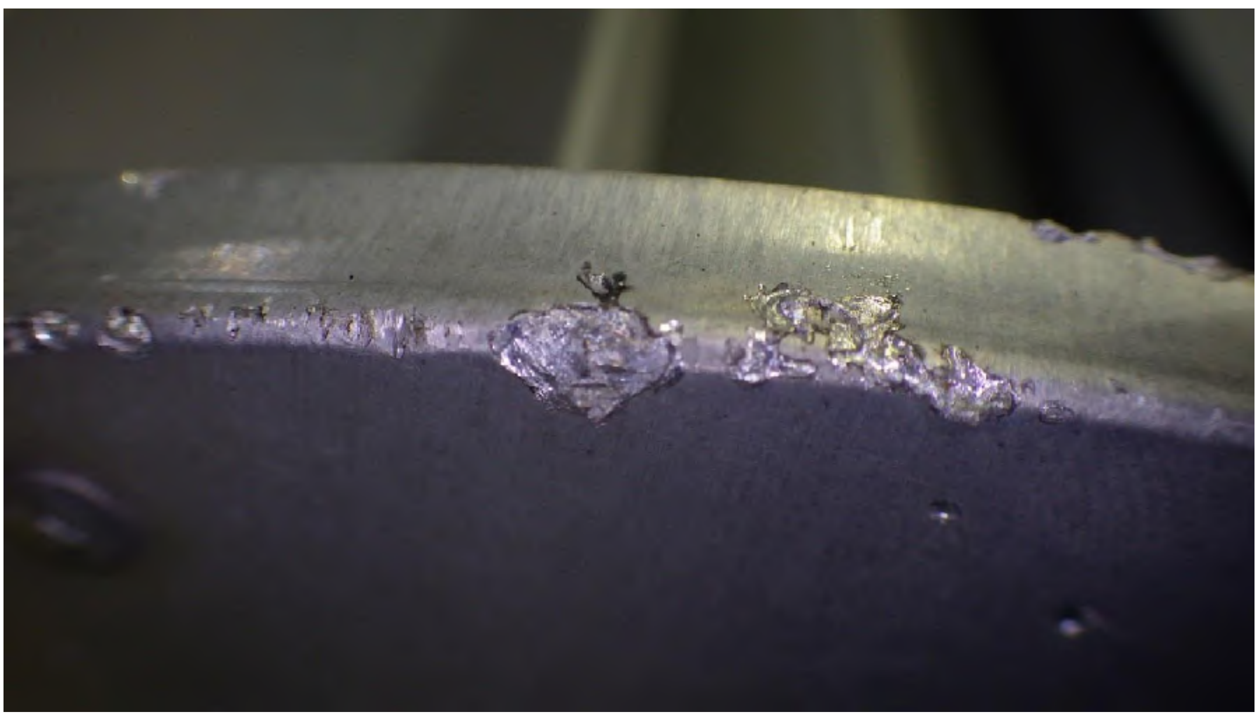

Figure 17. Example photograph of the electrical damage to the chimney cap.

Figure 18. Photograph of electrical damage on the inside surface of the flue piping at a location where adjacent sections of flue piping overlapped.

Figure 19. Photograph of electrical damage on the outside of the flue piping at a location where adjacent sections of flue piping overlapped.

Fireplace

As shown above in Figure 4, the fireplace comprised two compartments, a larger main compartment and a smaller compartment underneath with a flexible gas connector and the gas valve. There were two holes in the flexible gas connector that ran from the TracPipe CSST to the gas valve in the bottom compartment of the fireplace (see Figure 20). Both holes showed molten and resolidified metal around the edges (see Figure 21), indicating that they were caused by electrical arcing. Both holes were approximately elliptical, one had dimensions of approximately 1 mm x 4 mm, while the other had dimensions of approximately 1 mm x 3 mm.

In addition to the damage to the flexible gas connector, there was also damage to an electrical connector in the lower compartment of the fireplace, shown in Figure 22.

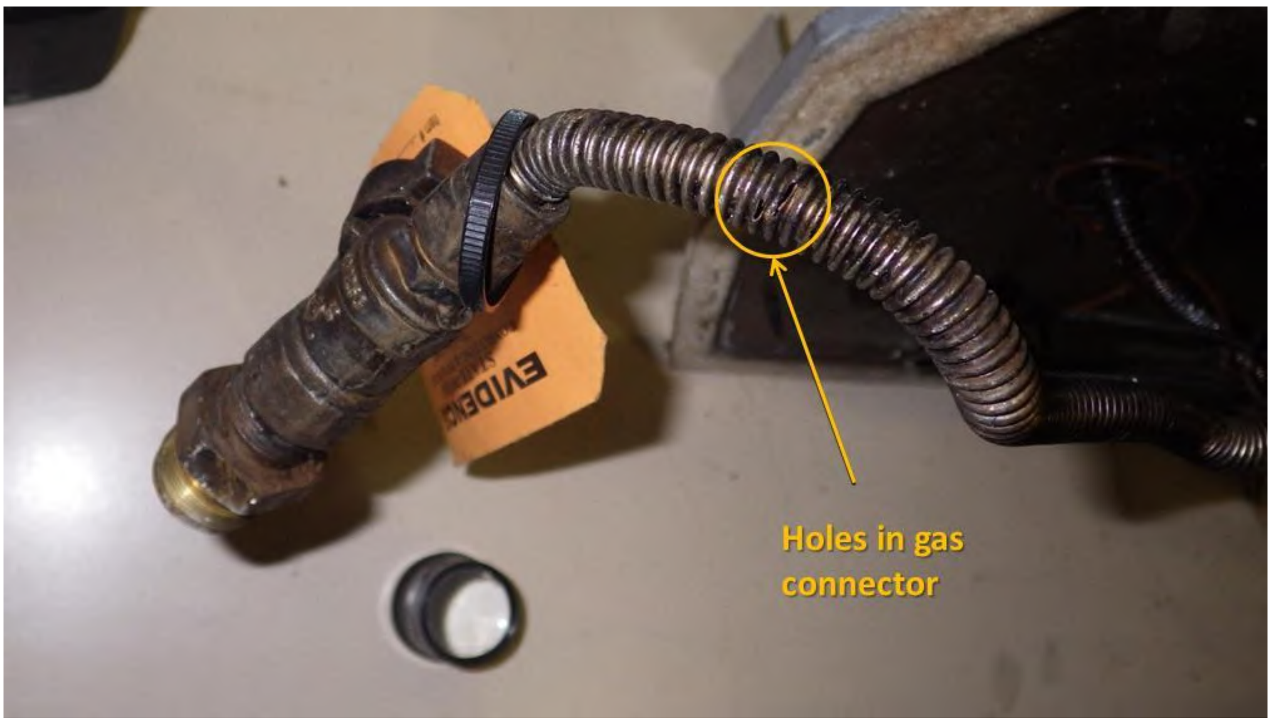

Figure 20. Photograph of the flexible gas connector to the gas valve in the lower compartment of the fireplace.

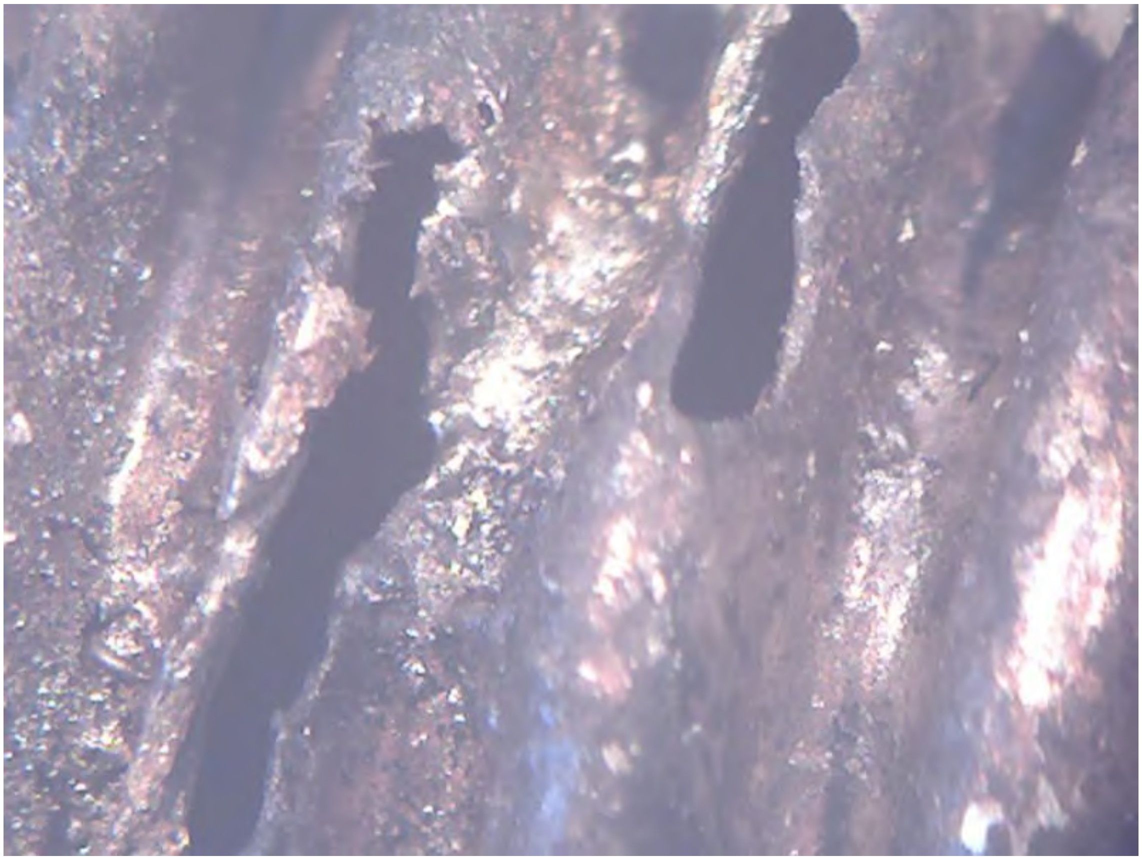

Figure 21. Optical microscope image of the two holes in the flexible gas connector.

Figure 22. Photograph of the damaged electrical connector located in the lower compartment of the fireplace.

TracPipe CSST

The CSST line to the living room fireplace was ½" diameter nominal TracPipe. Two holes were identified in the TracPipe CSST line: a larger hole (Figure 23) and a smaller hole (Figure 24). The larger hole was 1 foot 3 inches away from the end of the CSST that connected to the fireplace flexible gas connector, while the smaller hole was 3 feet 1 inch away. The location of the larger hole within the Gerard home is shown in Figure 25. The smaller hole was not identified at the scene examination. The larger hole was approximately rectangular with dimensions of 8 mm x 9 mm, while the smaller hole was approximately elliptical with dimensions of 2 mm x 2 mm. Both holes had molten and resolidified metal around the edge of the hole indicating that they were formed by electrical arcing.

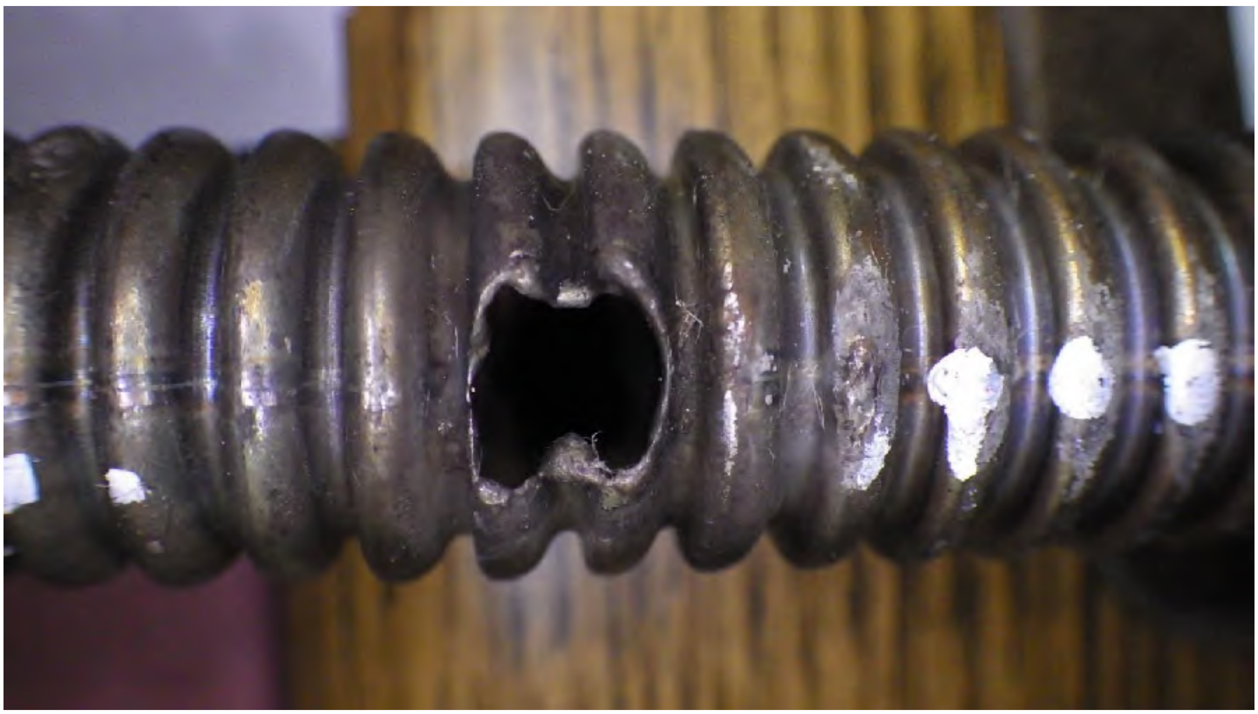

Figure 23. Photograph of the larger hole in the TracPipe CSST.

Figure 24. Photograph of the smaller hole in the TracPipe CSST.

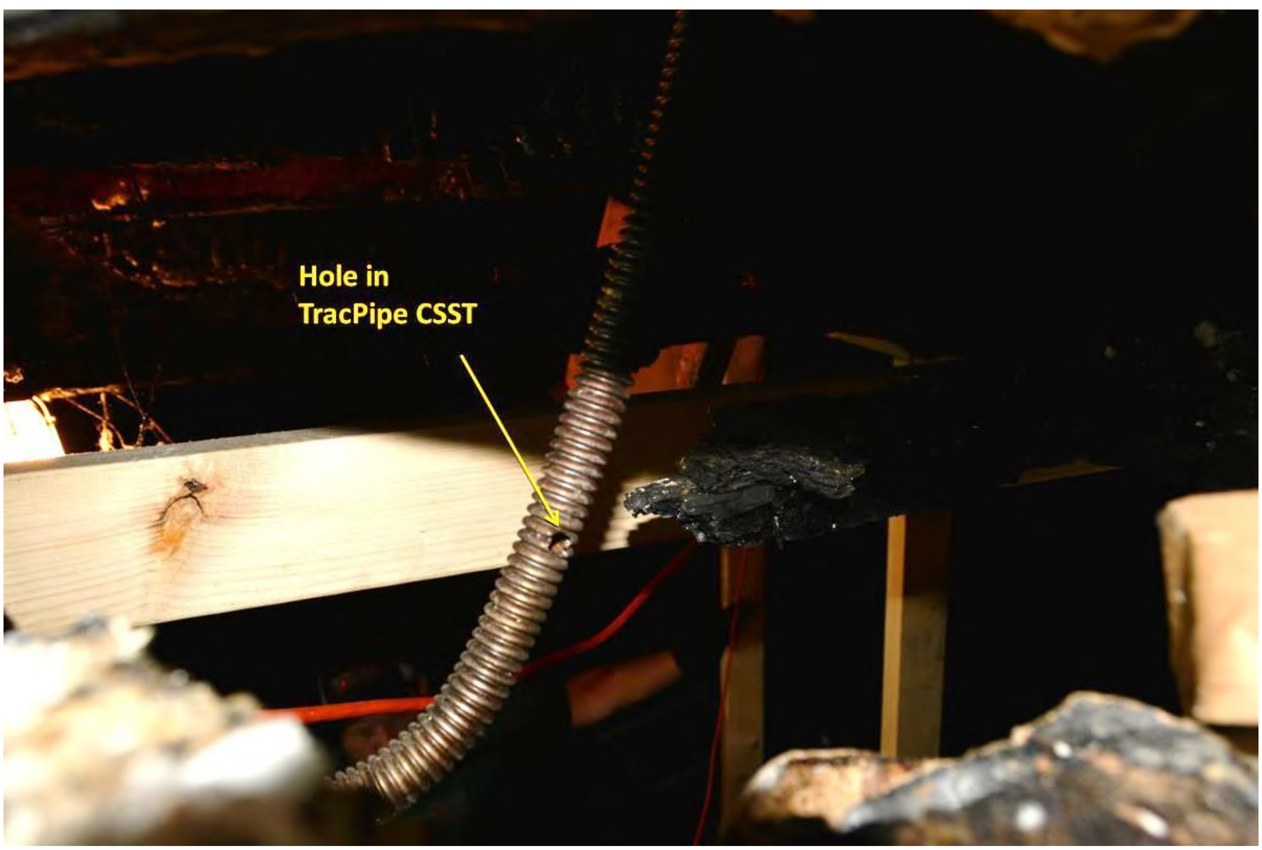

Figure 25. Photograph of the location of the larger hole in the TracPipe CSST.

Cause of the Gerard residence fire

The cause of the Gerard fire was lightning. Lightning directly struck the chimney cap for the living room fireplace. Electrical current from the lightning was conducted down the flue pipe and caused electrical damage at the connection between adjacent sections of the flue pipe. The lightning strike then energized the fireplace as well as the household gas system and household electrical system through their connections to the fireplace. The lightning strike caused electrical arcing within the lower compartment of the fireplace, igniting a fire. The lightning strike also likely resulted in additional locations of electrical arcing within the Gerard home involving the gas system, the electrical system, and/or the ducts for the HVAC system.

Lightning energy is well known to cause fires when it impacts residential structures. According to NFPA 921: Guide for Fire and Explosion Investigations (2014 edition), "Because the voltages and currents from lightning strikes are so high, arcs can jump at many places, cause mechanical damage, and ignite many kinds of combustibles."[9] A single lightning event is capable of igniting independent fires in multiple locations.

As described above, the maximum peak current of the lightning strokes most likely to have affected the Gerard home was -64.7 kA. Using a typical lightning current waveform of 10x50 µs[10], the -64.7 kA stroke was capable of depositing 4.1 C of charge at the chimney cap.

Cause of the holes in the gas lines

There were two holes in the flexible gas connector in the bottom compartment of the fireplace and two holes in the TracPipe CSST line, a larger hole and a smaller hole. All four holes showed evidence of molten and re-solidified metal. As the heat from a typical residential fire is insufficient to melt stainless steel, these holes were all formed by electrical arcing.

The two holes in the flexible gas connector and the smaller hole in the CSST each required approximately 1 C of charge to form.[11] Since the charge necessary to form the hole is lower than the total charge delivered by the lightning strike (approximately 4.1 C, as described above), the holes could have been caused by lightning. However, the larger hole in the CSST required approximately 24.9 C to form, or about 6 times the total charge delivered by the lightning strike. Thus, the larger hole could not have been caused by lightning.

The other potential source of electrical energy able to form the holes is the household electrical system. Exponent has performed testing in our laboratory that demonstrates that household electrical conductors protected by ordinary circuit breakers can form holes of a range of sizes in TracPipe during arcing events (see Appendix C). Such holes can be formed when insulated and

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9 NFPA 921 (2014) 9.9.4.2.2

10 A 10x50 µs waveform approximates the duration of a median waveform for negative strokes. See IEC Standard IEC62305-1 Protection Against Lightning (2006) Appendix A.

11 Based on a calculation using the dimensions of the holes and a formula provided by McEachron & Hagenguth. Effect of Lightning on Thin Metal Surfaces. IEEE Transactions,Vol 61, August 1942.

energized branch circuit wires and the jacketed TracPipe are exposed to a pre-existing fire which consumes the electrical insulation and TracPipe jacket.

Holes in the flexible gas connector

Mr. Gerard reported seeing flames in front of the fireplace that were a foot and a half in length very soon after hearing the lightning strike.[12] This observation indicates that gas leaking from the holes in the flexible gas connector was burning soon after the lightning strike, which indicates that the holes were caused by electrical energy from the lightning strike.

Larger hole in the TracPipe

As described above, the larger hole in the TracPipe CSST could not have been caused by lightning, thus it must have been caused by electrical energy from the household electrical system. There was a hole caused by electrical arcing in the HVAC duct in close proximity to the larger hole in the CSST (see Figure 8 above). The duct may have become energized by contact with a branch circuit wire during the fire and then arced to the CSST. It is also possible that both the hole in the CSST and the hole in the HVAC duct were caused by separate arcing events involving the household electrical system. The duct, branch circuit wires, and CSST were displaced during the fire and the subsequent firefighting efforts, thus their configuration at the time of the scene inspection does not necessarily reflect their configuration prior to the fire.

Smaller hole in the TracPipe

The smaller hole in the TracPipe could have been caused by electrical energy from the household electrical system or by electrical energy from the lightning strike. The opposing electrode for the arcing event could have been a branch circuit wire or the HVAC duct.

First fuel ignited

Exponent has performed testing that demonstrates that fuel gas escaping from a hole in TracPipe CSST is not ignited by the arcing event that formed the hole. As the concentration inside the CSST is 100% natural gas, an ignitable mixture of fuel gas only exists some distance away from the hole, after the gas has mixed sufficiently with air. Details regarding this testing are provided in Appendix D. Exponent has not performed this testing on a flexible gas connector, however the same physical principles apply.

Electrical arcing within the bottom compartment of the fireplace formed holes in the flexible gas connector resulting in a gas leak. There may have been additional arcing events within the fireplace. Electrical arcing ignited lightweight combustible material within the bottom compartment, such as dust, fibers, or other debris. This quickly resulted in ignition of the leaking gas from the holes in the flexible gas connector.

There may have been additional electrical arcing due to the lightning strike in the basement of the Gerard home resulting in an additional area of origin. There were many fuels in the area of the basement ceiling that could have been ignited by electrical arcing including: wood, wood

[12] Deposition of Mr. Gerard. December 29, 2016. Page 11.

fibers, saw dust (or other dust), or paper. Natural gas from the holes in the TracPipe CSST could not have been the first fuel ignited. The larger hole did not form until after the lightning strike, and the smaller hole may not have formed until after the lightning strike. Additionally, testing performed by Exponent showed that fuel gas escaping from a hole in CSST is not ignited by the arcing event that formed the hole. If the gas burned in the basement, it had to have been ignited by a separate fire ignited away from the holes, such as ordinary combustibles ignited by lightning-related electrical arcing.

The fire in the Gerard home would have occurred regardless of the presence of TracPipe CSST.

Rebuttals to Plaintiff Expert Reports

Both Mr. Hooker and Mr. Williams have expressed conclusions regarding the Gerard fire and the involvement of the TracPipe CSST that are either not correct, or not supported.

Mr. Hooker

Mr. Hooker claims that the origin of the fire was within the basement in the area where the CSST line passed through the floor to the fireplace. He believes that the first fuel ignited was natural gas escaping from the hole in the CSST supply line.[13] In his deposition, Mr. Hooker only refers to a single hole in the CSST line. There were two holes in the TracPipe CSST (a larger hole and a smaller hole), so it is not clear which hole Mr. Williams is referring to (he may be unaware that there were two holes). Regardless, Mr. Hooker is incorrect. As described above, the hole in the CSST line in the vicinity of the bottom of the fireplace was not caused by lightning and did not exist until later in the fire. Thus, gas escaping from that hole could not possibly have been the first fuel ignited. In addition, testing described in Appendix D shows that fuel gas escaping from a hole in TracPipe CSST is not ignited by the arcing event that caused the hole. This is because the gas is not premixed with air within the tubing, and the flow velocity out of the hole is too high to sustain ignition. Mr. Hooker has provided no testing or analysis to support his opinion that the escaping gas is ignited by the arcing event that causes the hole. In fact, he concedes that he does not know if the flow velocity affects its ignitability.[14]

Regarding the origin of the fire, Mr. Hooker was unware of the holes in the flexible gas connector located in the bottom compartment of the fireplace until after his investigation. He stated that those holes were secondary damage, so do not affect his investigation.[15] That conclusion is inconsistent with Mr. Gerard's description of the event. Mr. Gerard stated that he first observed flames coming from the front of the fireplace, consistent with burning natural gas from the holes in the flexible gas connector. Mr. Gerard did not observe flames anywhere else.

Mr. Hooker stated that he saw no evidence that the building was directly struck by lightning,[16] and further that there was no damage to the chimney cap that is consistent with lightning.[17] Mr. Hooker is incorrect. There were multiple locations on the chimney cap with molten and resolidified metal, as well as electrical damage at the seam between adjacent sections of the flue pipe. The damage to the chimney cap could only have been caused by electrical arcing, and there were no sources of electrical energy on the roof of the Gerard home that could have caused the damage other than lightning. The physical evidence unambiguously shows that the chimney cap was struck by lightning. Mr. Hooker has provided no alternative explanation of the damage.

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[13] Deposition of Jack Hooker. December 28, 2016. Pages 32-34

[14] Deposition of Jack Hooker. December 28, 2016. Page 82.

[15] Deposition of Jack Hooker. December 28, 2016. Page 69.

[16] Deposition of Jack Hooker. December 28, 2016. Page 45.

[17] Deposition of Jack Hooker. December 28, 2016. Page 84.

Mr. Williams

Mr. Williams states that the origin of the fire was along the CSST piping several feet away from the fireplace.[18] This is inconsistent with the observations of Mr. Gerard who saw flames coming from the front of the fireplace. Mr. Williams states that the "substantial hole" in the CSST was caused by "electrical arcing initiated by a nearby lightning strike."[19] There were two holes in the TracPipe CSST, so it is not clear which hole Mr. Williams is referring to (he may be unaware that there were two holes). Regardless, Mr. Williams failed to consider whether or not the household electrical system could have caused the holes in the CSST. As described above, the larger hole could not have been caused by lightning and thus could only have been caused by the household electrical system.

Mr. Williams states that CSST is "inherently dangerous" because it is susceptible to electrical arc damage.[20] Mr. Williams has provided no analysis as to the conditions necessary to damage CSST by electrical arcing, and no assessment as to the likelihood of such conditions occurring in a home. He also provided no comparisons with the susceptibility of other items found in a home to electrical arc damage. Many items normally found in a home are susceptible to damage from electrical arcing and many items in the home may be involved in the cause of a fire if the home is struck by lightning. The mere fact that CSST can be damaged by electrical arcing under certain circumstances does not render it unsafe.

Mr. Williams claims that rigid steel pipe is a safe alternative to CSST[21], but he provides no analysis of the risks or benefits associated with steel pipe as compared to CSST. As described in Appendix B, rigid pipe is more susceptible to leaks than CSST because leaks occur more often at fittings and rigid pipe systems require more fittings than CSST. Additionally, rigid pipe is more susceptible to damage caused by structural movement than flexible CSST.

Mr. Williams states that "improvements could be made to the stainless steel itself and the sheathing" of CSST,[22] but he provides no description of what those improvements might be, how they would render CSST less susceptible to electrical arc damage, or what impact they may have on the performance or safety aspects of CSST.

[18] Report by Michael Williams. February 20, 2017. Page 1.

[19] Report by Michael Williams. February 20, 2017. Page 1

[20] Report by Michael Williams. February 20, 2017. Page 2

[21] Report by Michael Williams. February 20, 2017. Page 2

[22] Report by Michael Williams. February 20, 2017. Page 2

Limitations

At the request of Omega Flex, Inc., Exponent conducted an investigation of the fire that occurred at the Gerard residence on May 29, 2013 for the purposes of an ongoing legal matter. The scope of services performed during this investigation may not adequately address the needs of other users of this report, and any re-use of this report or its findings, conclusions, or recommendations presented herein are at the sole risk of the user. The opinions and comments formulated during this assessment are based on observations and information available at the time of the investigation. No guarantee or warranty as to future life or performance of any reviewed condition is expressed or implied.

The findings presented herein are made to a reasonable degree of engineering certainty. Exponent has made every effort to accurately and completely investigate all areas of concern identified during this investigation. The data and opinions presented in this report are only those finalized at the time of its publication. If new data becomes available or there are perceived omissions or misstatements in this report, we ask that they be brought to our attention as soon as possible so that we have the opportunity to fully address them.

Appendix A – Material Reviewed

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2. Report by Jack Hooker. Septemeber 20, 2013
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Appendix B – CSST Background

TracPipe is a brand of Corrugated Stainless Steel Tubing (CSST). CSST is commonly used in residences to distribute fuel gas (either natural gas or propane) throughout the structure. CSST is often used either in conjunction with or in place of traditional black iron pipe. Black iron pipe, unlike CSST, must be installed in straight rigid lengths connected by multiple threaded fittings to change directions as the pipe is routed through walls, ceilings, and crawlspaces.

Safety of CSST

Since CSST is flexible, its installation only requires fittings at junctions and at connections to appliances. Thus the installation of CSST requires many fewer fittings than the installation of black iron pipe for a similar household configuration. This makes a CSST system less expensive to install than a black iron pipe system, and less prone to leaks. Gas leaks can occur at a fitting due to the fitting not being properly tightened, or to the fitting loosening over time, and are a common safety hazard in homes with gas service. CSST reduces the risk of gas leaks (due to the reduced number of fittings) and thus is a safer alternative than black iron pipe.

From 1980 to 1989, leaks or breaks were a contributing factor to more than 6,000 home fires per year on average.[1] These leaks and breaks must have occurred in black iron piping and copper tubing, because CSST was not yet in use. From 2002 to 2014, after the commercialization of CSST, fires due to leaks and breaks in gas piping where lightning was not the heat source continued to be far more common (35% of home fires involving natural or LP gas)[2], than fires caused by lightning igniting gas (only 7% of home fires involving natural or LP gas). During this period the average number of home fires started by lightning annually was about 4,400, the average number involving leaks and breaks in gas piping where lightning was not the heat source was about 1,000, and the average number involving the ignition of LP or natural gas by lightning was only about 200. From 2002 to 2014, the number of fires where LP or natural gas was reportedly ignited by lightning has shown no consistently increasing trend even though the amount of distributed CSST had increased 380% from the start of 2002 to the start of 2010.[3]

CSST also provides additional safety over black iron pipe in resisting damage from acts of nature, such as earthquakes, tornadoes, landslides, floods and hurricanes. Any event that causes a shift in the house foundation and/or structure may cause relative movement of two ends of a gas line. If that gas line is CSST, the inherent flexibility of CSST can accommodate

1 Data collected from Ahrens, Marty. "Home Structure Fires Involving Lightning and/or Natural Gas or LP-Gas," National Fire Protection Association, Report No. 2744, October 2016.

2 Data collected from Ahrens, Marty. "Home Structure Fires Involving Lightning and/or Natural Gas or LP-Gas," National Fire Protection Association, Report No. 2744, October 2016.

3 CSST distribution data from: SEFTIM, "Validation of Installation Methods for CSST Gas Piping to Mitigate Lightning Related Damage – Phase 1," Fire Protection Research Foundation, April 2011, pg. 53.

considerable movement without damage. If however, the gas line is black iron pipe, the pipe may break due to the stresses induced by the movement of the structure.[4]

CSST products are listed by Underwriters' Laboratories (UL) and have been independently tested and found to be suitable for the distribution of fuel gas within a structure in accordance with ANSI LC-1/CSA 6.26 Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing (CSST). In addition, CSST is required to be installed only by a qualified installer who has passed the manufacturer's certification/training program.[5]

Lightning and CSST

Lightning can enter a residence through multiple routes. Lightning may directly strike the side or roof of a residence. Metallic roof sections and roof penetrations such as flue pipes are especially common lightning strike locations, as they often represent the highest and most conductive path to ground within a structure. Lightning that directly strikes a utility, such as an overhead power line, may travel through the power lines into a residence. Lightning that does not directly strike a residence or utility may also enter a residence indirectly, through the ground. A lightning strike to a tree or directly to the ground can raise the electric potential of the ground nearby causing electrical energy to flow into a residence through the water pipes, a grounding rod, or through other utilities to the house. Once electrical energy enters a home it will flow through any and all conductive paths, including electrical wiring, communications wiring (such as cable service), metal ducts and vents, water piping, and gas piping.

Electrical current flows preferentially through paths of lower impedance. If two nearby conductors are not electrically connected (or are connected only through a high impedance path), a voltage (or electrical potential difference) can develop between the two conductors. If the voltage is high enough, an electrical arc can form between the conductors. The voltage threshold necessary to cause an arc depends on the distance between the conductors and the properties of the insulating material between them. The plastic coating on traditional yellow-jacketed CSST is designed to be a good electrical insulator with high electrical breakdown resistance. Air is a comparatively poorer insulator. For this reason, non-insulated conductors such as bare copper tubing or black iron pipe are more likely to be associated with an electrical breakdown event during a lightning strike than traditional CSST.

An electrical arc is a rapid discharge of electrical energy that generates both light and heat while transferring electric charge. An electrical arc is capable of melting copper wires, and igniting combustible materials such as wood, paper, or dust. A sufficiently energetic arc involving CSST can cause localized melting of the stainless steel, sometimes forming a hole in the pipe.

If a residence is subject to a lightning strike, the lightning is capable of causing significant damage to the electrical, plumbing, ventilation systems, and appliances of the home, as well as to combustible materials found within the structure such as wood studs, joists and roof shingles,

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4 *Testing to Compare the Seismic Response of TracPipe Flexible Gas Piping (CSST) with Black Steel Piping Systems Under Simulated Earthquake Induced Motions.* Report to Omega Flex 11/11/1998

5 ANSI LC-1/CGA 6.26-2005 Standard for Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing (CSST) Exhibit B: Items Unique to the United States, section B.1

often resulting in a fire. It is possible to significantly reduce the risk of damage to a home from lightning strikes using a Lightning Protection System[6], but due to the rarity of lightning strikes to homes, the authorities that have jurisdiction over the safe construction of homes throughout the U.S. do not require the use of Lightning Protection Systems (LPS) in homes and therefore their installation is voluntary.

Direct bonding of CSST

In order to significantly reduce the likelihood of perforation of traditional CSST due to lightning induced arcing, it is necessary to follow the manufacturer's instructions and bond the CSST directly to the household grounding electrode, following the principal of equipotential bonding. This requires the use of a large gauge wire between the CSST piping system and the electrical system ground.

During the electrical transients caused by lightning strikes, the voltage between CSST and other grounded conductors, such as electrical wires, will generally be higher when the electrical impedance between them is higher. A higher voltage increases the possibility of arcing. Therefore reducing the electrical impedance to ground and the electrical impedance between adjacent conductors (through direct bonding) reduces the likelihood of an arc occurring.

If an arc does occur, direct bonding also reduces the amount of charge transfer through the arc by providing an alternate low-impedance path for the flow of current. Since the amount of charge transferred dictates both whether or not a hole is formed[7] and the size of the hole if it does form[8], direct bonding can reduce the size of the hole or prevent a hole from occurring, even if an arc occurs.

Testing on the effectiveness of direct bonding by Kraft & Torbin[9] and simulations by the Gas Technology Institute[10] both showed that the presence of a bond wire prevents a hole from forming in CSST during a simulated lightning event. For a sufficiently short bond wire, the arcing was prevented altogether.

Equipotential bonding of CSST will not prevent all lightning induced fires in homes. It only reduces the likelihood of CSST (and other equipotentially bonded systems) from being involved in lightning induced arcing. Irrespective of the presence of CSST in the home, arcing caused by a lightning strike may ignite nearby combustibles such as wood dust, pollen, paper products, etc, starting a fire in the residence. The most effective way to prevent house fires caused by direct

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[6] NFPA 780: Standard for the Installation of Lightning Protection Systems provides recommendations on installing a lightning protection system.

[7] Lightning Technologies Inc. "Dielectric breakdown voltage and current conduction tests of OmegaFlex flexible gas piping." July 9, 2003.

[8] Hagenguth, J.H. "Lightning Stroke Damage to Aircraft." *AIEE Transactions*. Volume 68. 1949.

[9] Kraft, B. & Torbin, R. "Effectiveness of Direct Bonding of Gas Piping in Mitigating Damage from an Indirect Lightning Flash." August 2007.

[10] Hammerschmidt, A. "Validation of Installation Methods for CSST Gas Piping to Mitigate Indirect Lightning Related Damage." Final Report. Gas Technology Institute. September 5, 2013.

lightning strikes is to install an NFPA 780-compliant lightning protection system. This is true independent of the presence of CSST in the home.

Appendix C – Branch Circuit Wire Testing

The yellow jacket on TracPipe and the insulation on typical household branch circuit wiring prevent arcing at normal household voltages. However, household voltage can cause arcing between TracPipe and electrical wiring in the presence of a fire after this insulation has been compromised. Exponent has performed testing to demonstrate this mechanism, described below.

A 14 AWG branch circuit cable (type NM-B) was connected in series to a 15 amp rated circuit breaker which was supplied by a 120 VAC electrical outlet protected by a 20 amp breaker. The live (or hot) conductor was separated from the neutral and ground conductors and placed near a length of TracPipe that was connected to a grounded water pipe using a stainless steel hose clamp. The insulating jacket on both the TracPipe and the live conductor was kept intact. A propane diffusion flame was then applied under the TracPipe and live conductor. A photograph of a sample test is shown in Figure 1.

Once the insulation on the conductor and the TracPipe began to burn away, an electrical arc occurred between the conductor and the TracPipe, forming a hole in the TracPipe. An optical microscope image of one example hole from such a test is shown in Figure 2. This testing demonstrated that energized electrical wires can cause a hole in TracPipe in the presence of a pre-existing fire.

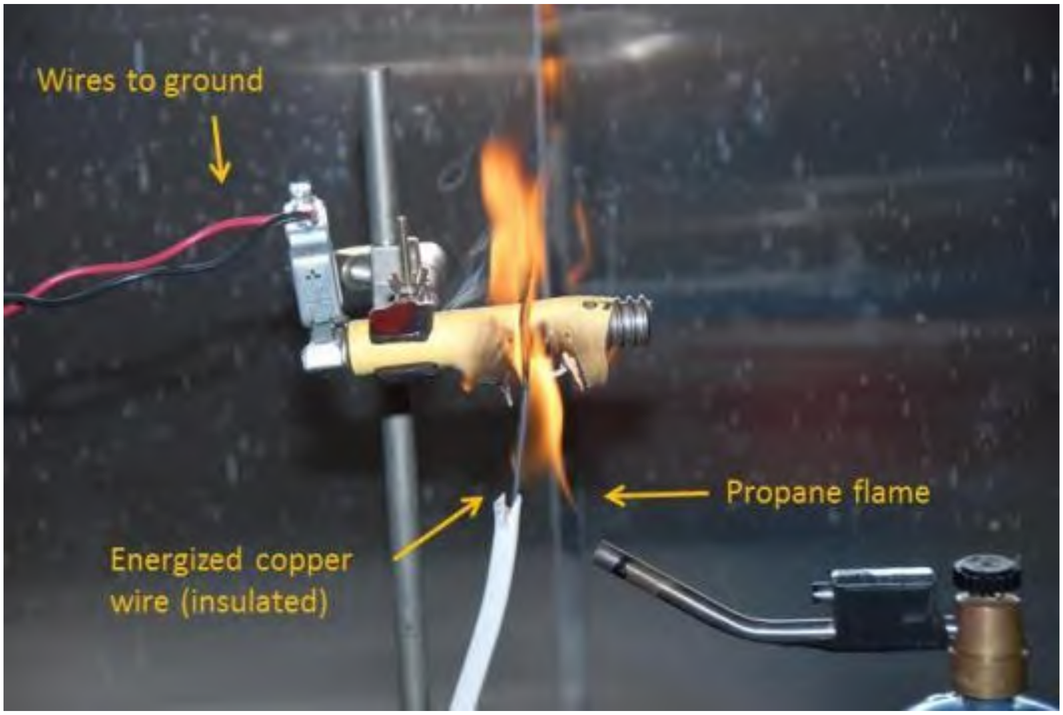

Figure 1. Photograph of the testing of TracPipe in proximity with energized branch circuit wiring in the presence of a flame.

Figure 2. Optical microscope image of hole formed in TracPipe by household electricity in a flame.

Testing of non-grounded TracPipe with three conductors

Additional testing was performed in which the TracPipe was not grounded and all three wires (hot, neutral, and ground) were electrically connected and kept in place in close proximity to the TracPipe (see Figure 3). As in the testing described above, the branch circuit wiring was energized with typical 120 VAC and a diffusion flame was placed underneath the TracPipe and wiring.

Even with the neutral and ground wires running along the hot (energized) wire, the hot wire arced to the TracPipe rather than to the neutral or to the ground, resulting in the formation of holes in the TracPipe (see Figure 4 and Figure 5). The reason arcing occurred to the TracPipe is because the fire consumed the outer portions of electrical insulation before it consumed the insulation between the individual conductors. This is likely due to the protection of the insulation material between conductors from the flame by the conductors themselves.

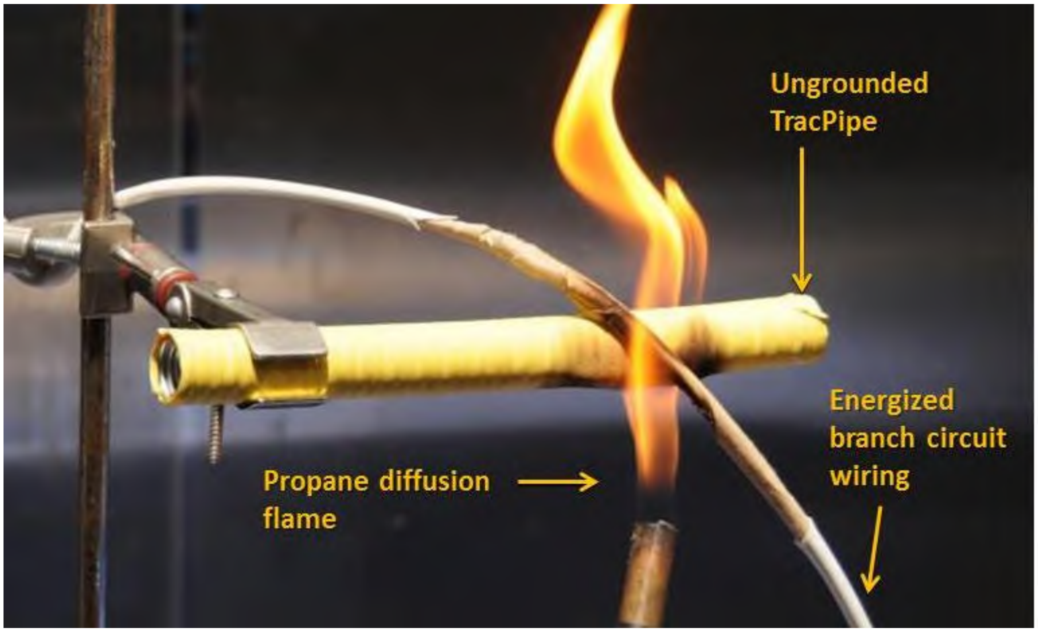

Figure 3. Photograph of testing with TracPipe and with all three conductors of branch circuit wiring.[1]

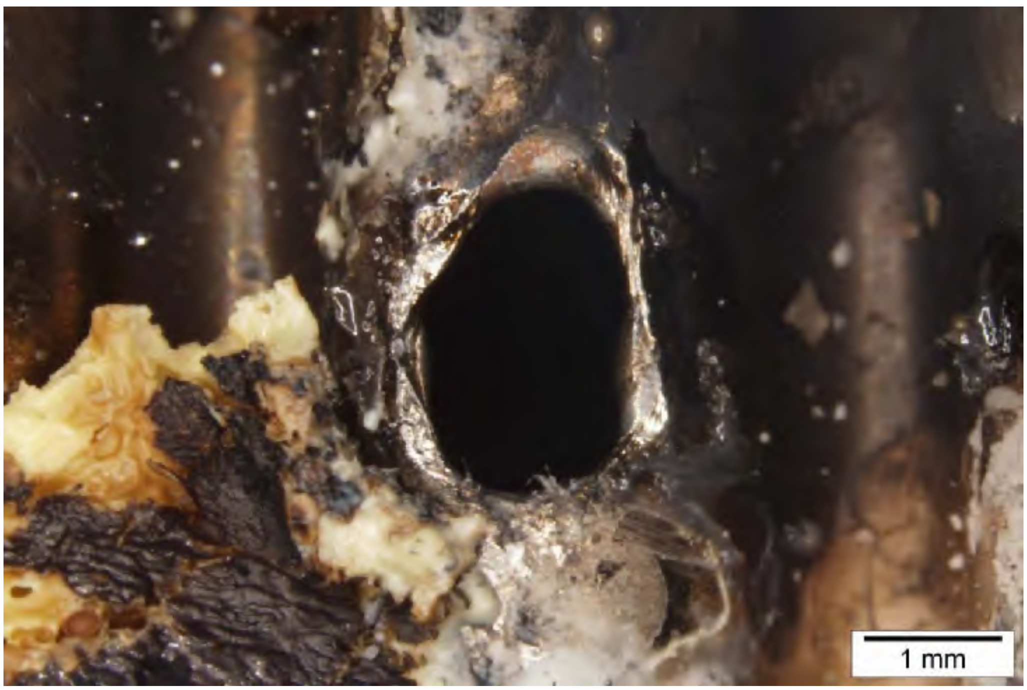

Figure 4. Optical microscope image of an example hole formed in TracPipe by a a three-conductor branch circuit wire.

[1] The outside plastic jacketing of the NM-cable in the image was cut away to reduce the time it took for an arcing event to occur. The paper liner, and individual conductor insulation remained intact, as did the relative positioning of the conductors.

Figure 5. Optical microscope image of two example holes formed in TracPipe by a a three-conductor branch circuit wire.

Testing of TracPipe with varying branch circuit resistances

Typical household circuit breakers operate by one of two mechanisms, a magnetic trip mechanism or a thermal trip mechanism, depending on the current flowing through the breaker. At high currents, the magnetic trip mechanism is triggered, and the circuit breaker opens quickly. At lower currents, the magnetic trip mechanism does not operate and the circuit breaker opens when the thermal mechanism is triggered. The rate at which the thermal mechanism triggers depends on the current, but can be on the order of 1 second or more. A chart depicting the time of current flow before a typical breaker will trip versus the amount of current flowing is provided in Figure 6.

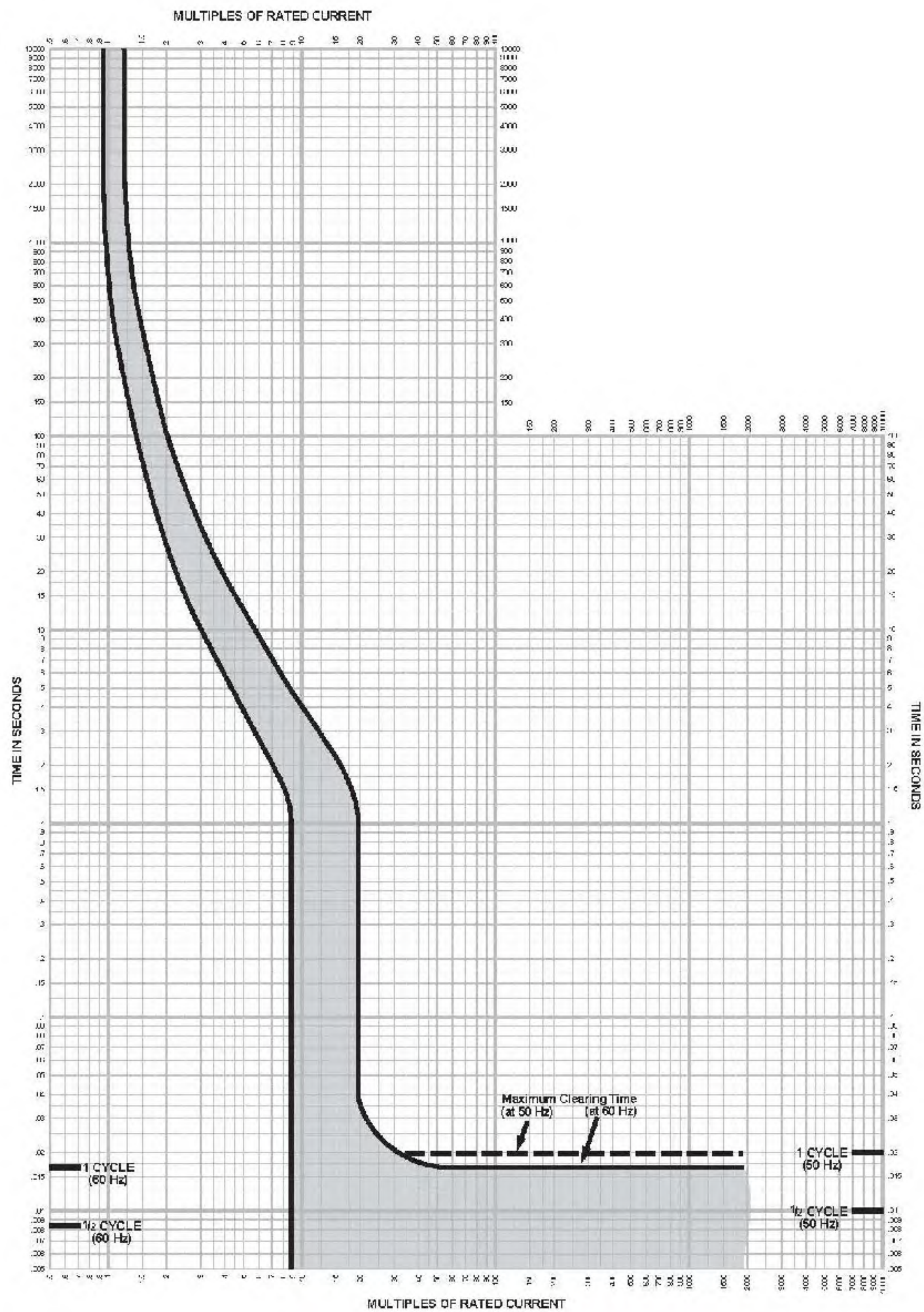

Figure 6. Circuit breaker trip-time chart.[2]

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[2] Square D. Data Bulletin: Circuit Breaker Characteristic Trip Curves and Coordination. Bulletin No. 0600DB0105. August 2001.

The much longer tripping time for the thermal mechanism means that the total amount of charge transfer for arcing events in this mode can be considerably higher compared to the magnetic mechanism. For example, a 50 A (average) fault that lasts 1 second (thermal mechanism) will deliver 50 C of charge whereas a 200 A (average) fault that lasts 10 milliseconds (magnetic mechanism) will only deliver 2 C of charge. Since the size of holes created by electrical arcs to metal tubing increases with increased charge transfer,[3] arcing events that cause the circuit breaker to trip via the thermal mechanism can lead to much larger holes than higher current arcing events which trip the breaker much quicker (i.e. via the magnetic mechanism).

Exponent conducted some tests to demonstrate this effect. A schematic diagram of the test setup is shown in Figure 7. An insulated 14 AWG copper wire was connected through a resistor to a 15 Amp circuit breaker, which was connected to a wall outlet at 120 VAC. The resistance of the resistor could be varied to different levels between 1/8 Ω to 2 Ω. The wire was laid across a section of TracPipe with the yellow jacket intact. The TracPipe was connected to the neutral of the wall outlet. The circuit breaker was then energized and a propane diffusion flame was applied to the area where the insulated copper wire was in contact with the TracPipe. As the insulation on the wire and the jacket on the TracPipe burned away, an electrical arc occurred between the wire and the TracPipe, resulting in a hole or holes in the TracPipe.

This test procedure was repeated with the resistor set to different resistances. By selecting different values of the resistance, the current that flowed through the arc could be controlled such that the circuit breaker tripped with either the magnetic or thermal mechanism. As expected, the hole size varied when the resistance (and thus the total charge transfer) was altered. Larger holes were observed with resistance values that caused the circuit breaker to trip with the slower thermal mechanism. Examples of holes from this testing are shown in Figure 8 and Figure 9 and Figure 10. These holes are irregular in shape and cross one or more corrugations of the TracPipe, exhibiting peninsulas or fingers at the edge of the hole.

[3] McEachron & Hagenguth. Effect of Lightning on Thin Metal Surfaces. IEEE Transactions. Vol. 61, August 1942.

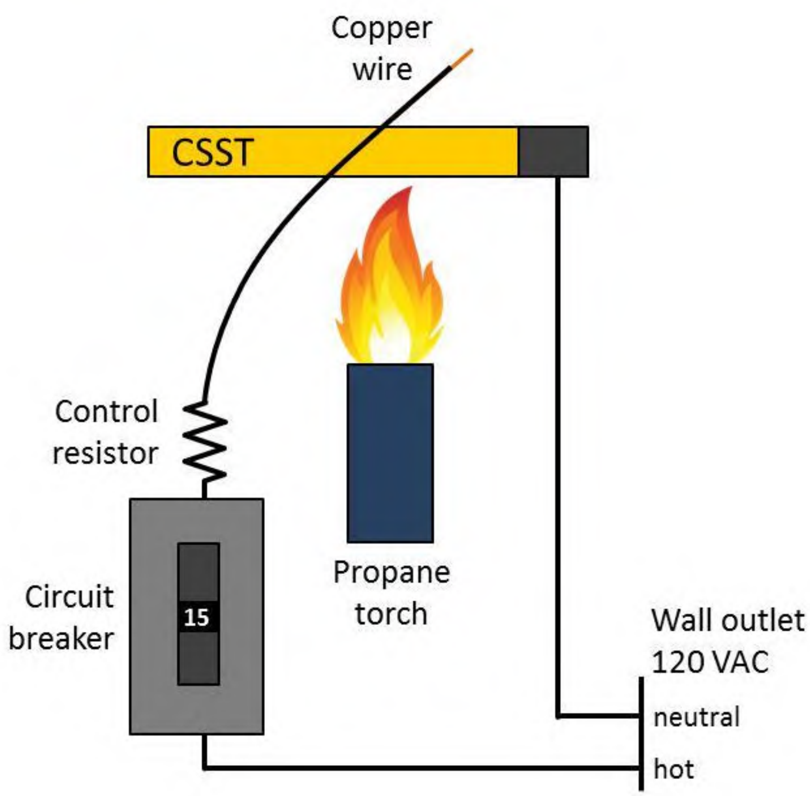

Figure 7. Schematic diagram of the experimental setup used for variable resistance arc testing.

Figure 8: Photograph of a hole (2 by 2 mm) in TracPipe created using a resistance of 0.15 Ω.

Figure 9: Photograph of a hole (10 by 6 mm) in TracPipe created using a resistance of 0.70 Ω.

Figure 10: Photograph of three holes (4 mm by 3 mm; 6 mm by 2 mm; 11 mm by 4 mm) in TracPipe created using a resistance of 0.54 Ω.

Hole Morphology

Testing with branch circuit wiring has also allowed Exponent to examine the morphological characteristics of such holes. Several examples are shown in Figure 11 through Figure 13 The character of the hole is similar to holes in TracPipe that were allegedly caused by an electrical arc due to lightning. This similarity makes it impossible to identify the source of electrical energy that caused the hole (lightning or household electricity) from an examination of the hole alone.

Through this testing, Exponent also determined that evidence of the opposing electrode is not always transferred between the electrodes. For example, some of the TracPipe samples inspected by SEM/EDS (which were known to have been caused by household electrical arcing from a copper branch circuit wire) did not show any evidence of copper transferred to the stainless steel. As such, a hypothesized opposing electrode cannot be ruled out based solely upon the lack of elemental transfer from the opposing electrode to the area around the hole.

Figure 11. Image of a hole formed in TracPipe by household electricity in a flame.

Figure 12. Image of a hole formed in TracPipe by household electricity in a flame.

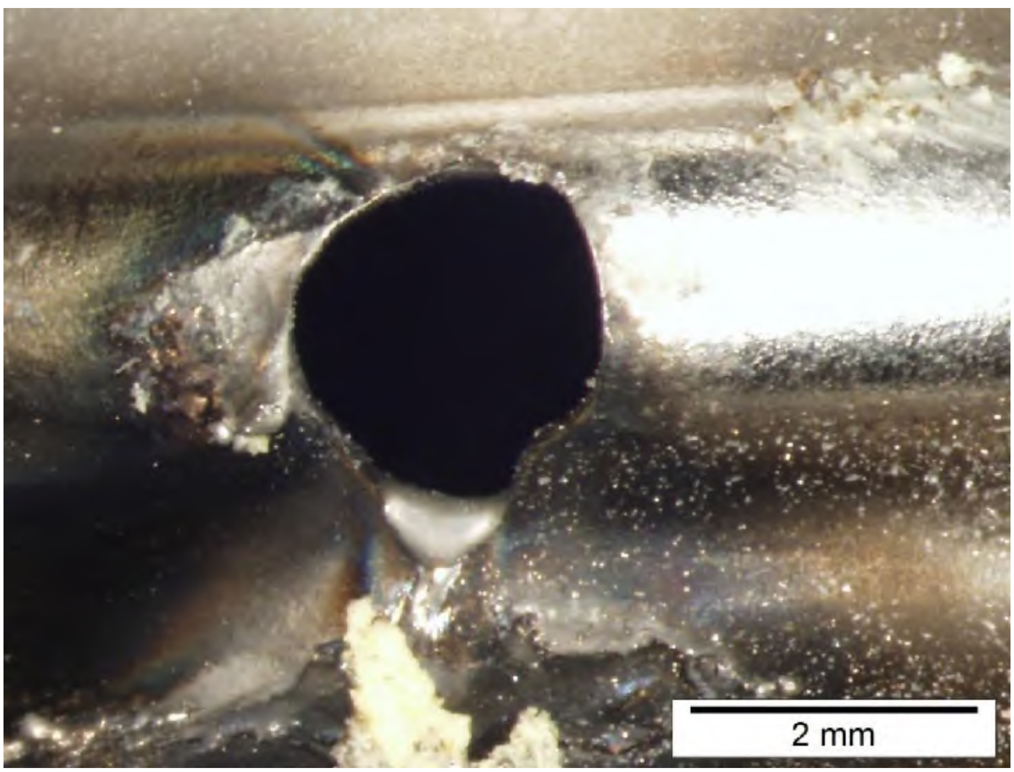

Figure 13. Image of a hole formed in TracPipe by household electricity in a flame.

The following testing materials are provided with this appendix:

- Exponent's TracPipe and Branch Circuit Fire Testing

Appendix D – Ignition Testing

Flame Ignition testing

Exponent performed testing to determine: (A) whether or not fuel gas leaking from a hole in a CSST gas line can be ignited at the hole and (B) to examine the character of the flame. Video of this testing is provided with this appendix. Testing was performed with both natural gas and propane. A ½" section of TracPipe was connected to a natural gas supply at approximately 7 inches water column (and a propane gas supply at approximately 11 inches water column). The insulation of the TracPipe was removed, and holes of varying size were pre-drilled in the TracPipe. Exponent then attempted to ignite the escaping gas using a flame from a butane lighter placed right at the hole. Regardless of the hole size, Exponent was unable ignite the gas at the hole. If an ignition source was placed a few inches away from the hole, the gas could be ignited, but the flame would quickly blow off and extinguish when the butane lighter was removed.

The reason that fuel gas cannot be ignited at the hole is because the jet exit velocity is too high, and the fuel gas has not been premixed with air. Thus a secondary ignition source, away from the hole where the gas velocity has decreased, and the gas has sufficiently mixed with air is required in order for ignition to occur.

Exponent has also performed similar tests where an aluminum plate was placed at various distances away from the hole. Video of this test is also provided. Ignition of the natural gas escaping from the hole was attempted with a butane lighter. Even with the presence of an obstruction, the natural gas did not ignite with the ignition source at the hole. This is because the presence of an obstruction inches from a hole will not affect the gas jet dynamics right at the hole. There will still be a rapid jet of un-mixed fuel escaping from the hole that cannot be ignited. The obstruction does allow a flame of fuel gas to be sustained, if the gas is first ignited inches away from the hole.

The following testing materials are included with this Appendix:

- Exponent's natural gas ignition and flame height testing videos dated August 19, 2011
- Exponent's propane ignition testing videos dated May 3, 2012
- Exponent's natural gas ignition tests with obstructions videos dated June 4, 2012

Arc Ignition Testing

Exponent performed arc testing between an energized copper wire and an insulated section of TracPipe that was pressurized with natural gas. The copper wire electrode was connected to two electrical sources: a high voltage source capable of supplying up to 25 kV[1] and a typical AC electrical outlet at either 120 VAC or 240 VAC. A schematic of the test setup is shown below in Figure 1.

[1] The high voltage source was a Hipotronics model HD100 series hipot tester.

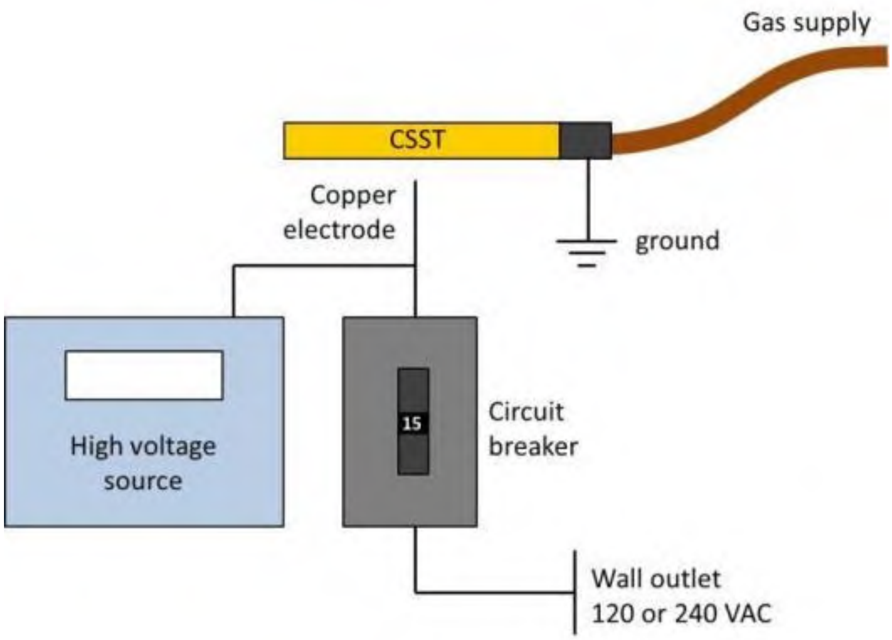

Figure 1. Schematic diagram of the test setup used for arc ignition testing.

The insulating jacket of TracPipe has a dielectric strength of approximately 24 kV.[2] The high voltage equipment used was capable of generating an arc through the TracPipe jacket when the copper electrode was placed directly against the outside surface of the jacket, but to allow the copper electrode to be positioned farther away from the tubing wall while still creating an arc to the CSST, a pin prick was made through the TracPipe jacket at a ridge of the corrugated tubing. This provided a localized decrease in dielectric strength of the insulation.

The high voltage supply could only supply a relatively low current that was not capable of forming a hole in TracPipe. To overcome the current limit, the copper electrode was connected in parallel to an electrical outlet after passing through an additional 15 Amp circuit breaker.[3] Utilizing this circuit design, a high voltage arc was initiated by the high voltage source that was then followed by the electrical current from the wall outlet as a result of the low resistance of the low current arc. The resulting arc had a peak current of about 300 Amps and a duration of about 5 ms. The peak current and duration varied from test to test.

The exemplar TracPipe was connected to a natural gas supply on one end and capped at the other after being purged of any air. The setup was then checked for any gas leaks. As the presence of confinement (in the form of floor joists or other obstructions) is known to have an effect on whether or not a flame can be sustained, an acrylic sheet with a 90 degree bend was placed over the TracPipe. This acted as an obstruction for any resulting gas jet. A small opening was drilled into the acrylic sheet to position the copper electrode. Photographs of the test setup are shown below in Figure 2 and Figure 3.

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2 This was measured by testing performed by LTI (Lightning Technologies Incorporated). Exponent confirmed this value through utilizing this test setup.

3 The laboratory electrical outlets are protected by a 20 Amp breaker. The 15 Amp circuit breaker was used to protect the laboratory branch circuit wiring and to avoid having to repeatedly reset the breaker at the panel.

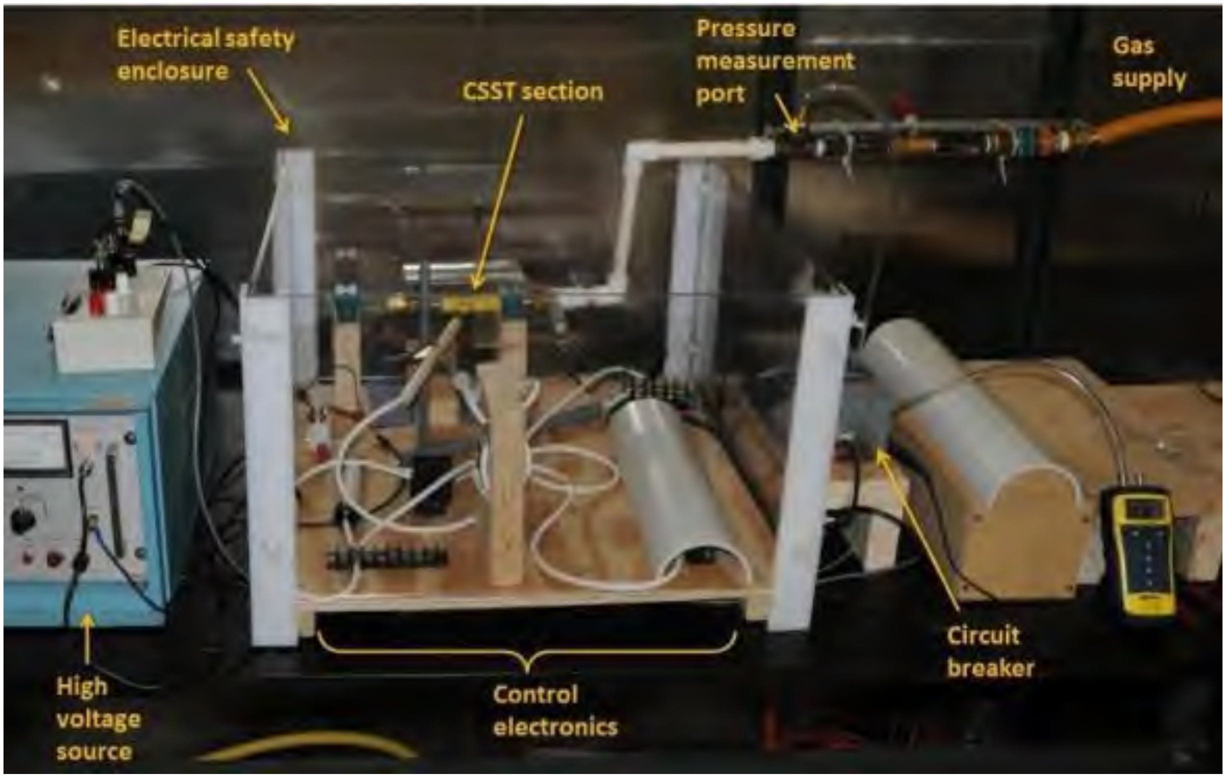

Figure 2. Photograph of the high voltage arc ignition test setup.

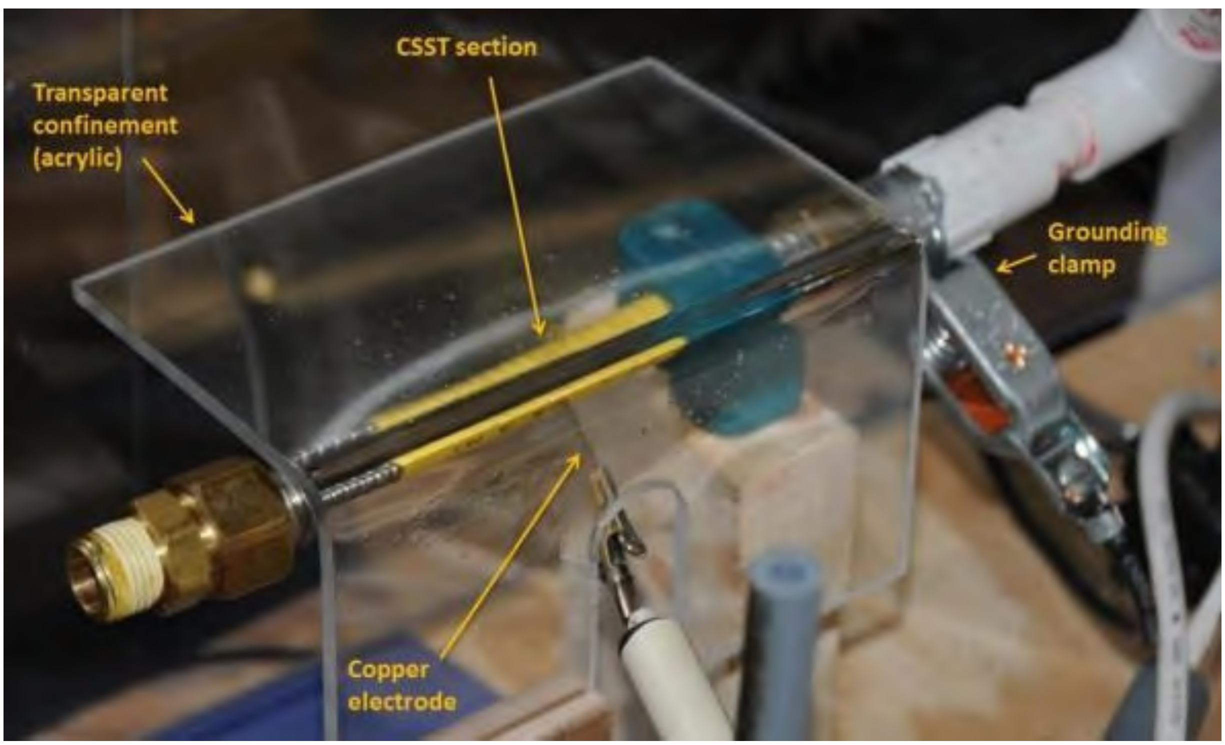

Figure 3. Photograph of the setup used for the high voltage arc ignition testing.

Five tests were performed. Each test resulted in the formation of a hole in the stainless steel ranging in diameter from 1 to 2 mm. Notably, the hole in the insulation after the arc formed was found to always be significantly smaller than the hole that formed in the stainless steel behind it (see Figure 4). The arcing event which caused the hole in the CSST was not able to ignite the gas escaping from the hole in any of the five tests. After the testing, a flame from a butane lighter was brought into the resulting gas jet downstream from the hole to demonstrate that the gas could be ignited by a separate ignition source, such as an existing fire. Video and photographs from this testing are included with this report.

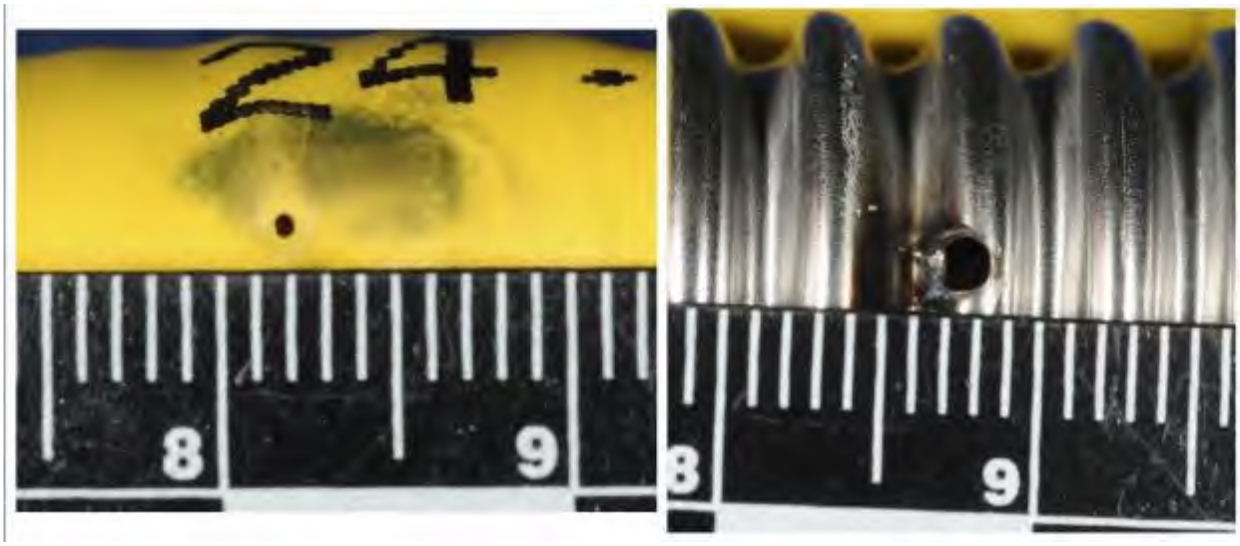

Figure 4. Photographs of the hole in the jacket (left) and the hole in the underlying stainless steel wall (right) after an arc test. Note the ruler increments are in millimeters.

The following testing materials are included with this Appendix:

- Exponent's arc ignition testing videos and photos dated August 14, 2012

Appendix E – Dr. Morse's Curriculum Vitae

Exponent®
Engineering & Scientific Consulting

Timothy L. Morse, Ph.D., P.E., CFEI

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Professional Profile

Dr. Morse specializes in the engineering analysis and experimental testing of thermal and flow processes and equipment. His project experience has included turbines, compressors, valves, heat exchangers, boilers, furnaces, autoclaves, heat transfer systems, flammable liquids, cryogenic liquids, and medical devices. Dr. Morse has performed engineering analysis for the oil and gas industry, ranging from natural gas extraction facilities to retail motor fuel stations. He also has experience with offshore facilities. Dr. Morse has performed analysis on wind farms and investigated wind turbine failures and wind turbine fires. He has also applied his expertise to intellectual property matters involving mechanical engineering principles, including thermal or flow processes.

Dr. Morse also applies his expertise to the investigation and prevention of fires, explosions, and equipment failures. He has conducted fire origin and cause investigations involving electrical appliances, electrical systems, consumer products, boilers, furnaces, stoves and other combustion equipment. Dr. Morse has also investigated the origin and cause of fires in motor vehicles, including post-collision motor vehicle fires. Dr. Morse has experience in the testing and analysis of HVAC systems and components, including the analysis of the production and spread of carbon monoxide. He has significant experience with instrumentation and experimental measurement techniques in flow and thermal systems, including flow visualization and flow velocity measurement with laser diagnostic and acoustic diagnostic methods.

Dr. Morse has investigated flow-induced vibration issues over a wide range of applications including heat exchanger tube bundles, pipelines, and offshore structures. Prior to joining Exponent, Dr. Morse was a researcher in the Fluid Dynamics Research Laboratories at Cornell University where he conducted research on the wakes of stationary and oscillating structures in a flow and particularly on how flow-induced vibration due to vortex shedding causes fatigue and failure of structures.

Academic Credentials & Professional Honors

Ph.D., Mechanical Engineering, Cornell University, 2009

M.S., Mechanical Engineering, Cornell University, 2007

B.E., Mechanical Engineering, Cooper Union, *summa cum laude*, 2003

National Science Foundation Fellowship, 2004-2008

National Defense Science and Engineering Graduate Fellowship, 2004-2007

Cornell University Graduate Fellowship, 2003

Tau Beta Pi Fellowship, 2003

New York Association of Consulting Engineers Scholarship, 2002

Tau Beta Pi Engineering Honor Society, 2002

Pi Tau Sigma Mechanical Engineering Honor Society, 2002

Licenses and Certifications

Licensed Professional Mechanical Engineer, California, #35464

Licensed Professional Mechanical Engineer, New Hampshire, #13976

Licensed Professional Engineer, Kansas, # PE24740

Licensed Professional Engineer, Massachusetts, #52419

Licensed Professional Engineer, Pennsylvania, #PE084735

Licensed Professional Engineer, Rhode Island, #PE.0011724

Certified Fire and Explosion Investigator (CFEI) in accordance with the National Association of Fire Investigators

Hazardous Waste Operation and Emergency Response Certification, 29 CFR 1910.120

Professional Affiliations

American Society of Mechanical Engineers

National Fire Protection Association

National Association of Fire Investigators

American Wind Energy Association

- Wind Standards Committee Member

Publications

Ponchaut NF, Morse TL, Bigham GN, Castro J. Degassing Africa's Lake Kivu for population safety and power generation. Scandinavian Oil-Gas Magazine No. 11/12 2016; 44:26-29.

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Gan YX, Kysar JW, Morse TL. Cylindrical void in a rigid-ideally plastic single crystal II: Experiments and simulations. International Journal of Plasticity 2006; 22(1):39-72.

Morse TL, Williamson CHK. Employing controlled vibrations to predict fluid forces on a freely vibrating cylinder. Proceedings, 4th Conference on Bluff Body Wakes and Vortex-Induced Vibration (BBVIV-4), Santorini, Greece, 2005.

Presentations

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Marr KC, Verghese PM, Braff WA, Morse TL. Analysis of arc erosion on thermal switch contacts. International Symposium on Fire Investigation, University of Maryland, September 2014.

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Morse TL, Williamson CHK. Predicting the response of a cylinder undergoing vortex-induced vibration using controlled vibrations. 58th Annual Meeting of the American Physical Society (APS) Division of Fluid Dynamics, Chicago, IL, 2005.

Morse TL, Williamson CHK. Forces on a cylinder with periodic transverse motion in a free stream. 57th Annual Meeting of the American Physical Society (APS) Division of Fluid Dynamics, Seattle, WA, 2004.

Peer Reviewer

Journal of Fluid Mechanics

Physics of Fluids

Journal of Fluids and Structures

Journal of Wind Engineering

International Journal of Heat and Fluid Flow

Journal of Loss Prevention in the Process IndustriesEnergy and Fuels

Expert Testimony of

Timothy L. Morse, Ph.D. P.E.

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Unitrin Auto & Home Insurance Company as Subrogee of Shamsher Shamsher v. K. Hovnanian Homes of Maryland, LLC et al.	Deposition	The United States District Court for the District of Maryland Case No. 1:11-CV-0011-RDB	2012
General Trading Company, Inc. v. United Water New Jersey, Inc.	Deposition	Superior Court of New Jersey Law Division Bergen County Docket No. BER-L-3993-14	2015
Southern California Edison Company; Edison Material Supply, LLC; San Diego Gas & Electric Company; and City of Riverside v. Mitsubishi Nuclear Energy Systems, Inc. and Mitsubishi Heavy Industries, Ltd.	Deposition Trial	International Chamber of Commerce International Court of Arbitration Case No. 19784/AGF/RD	2016
Marc Shapiro v. The L.S. Starrett Company	Hearing	American Arbitration Association Case No. 01-16-0001-7896	2016
Joseph and Britain Paquette v. A+ Chimney Service	Deposition	United States District Court for the District of Vermont Case No. 5:15-cv-69	2017
Carl P. Wilson, Judith L. Wilson, and CPW Enterprises, LLC v. Pepperidge Farm, Inc. and 375 Harvard Realty LLC	Trial	Commonwealth of Massachusetts Middlesex Superior Court Docket No. MICV2012-00515	2017

Compensation

Exponent Engineering, P.C. is compensated at $345.00 per hour for Dr. Morse’s time.

Updated: March 2017